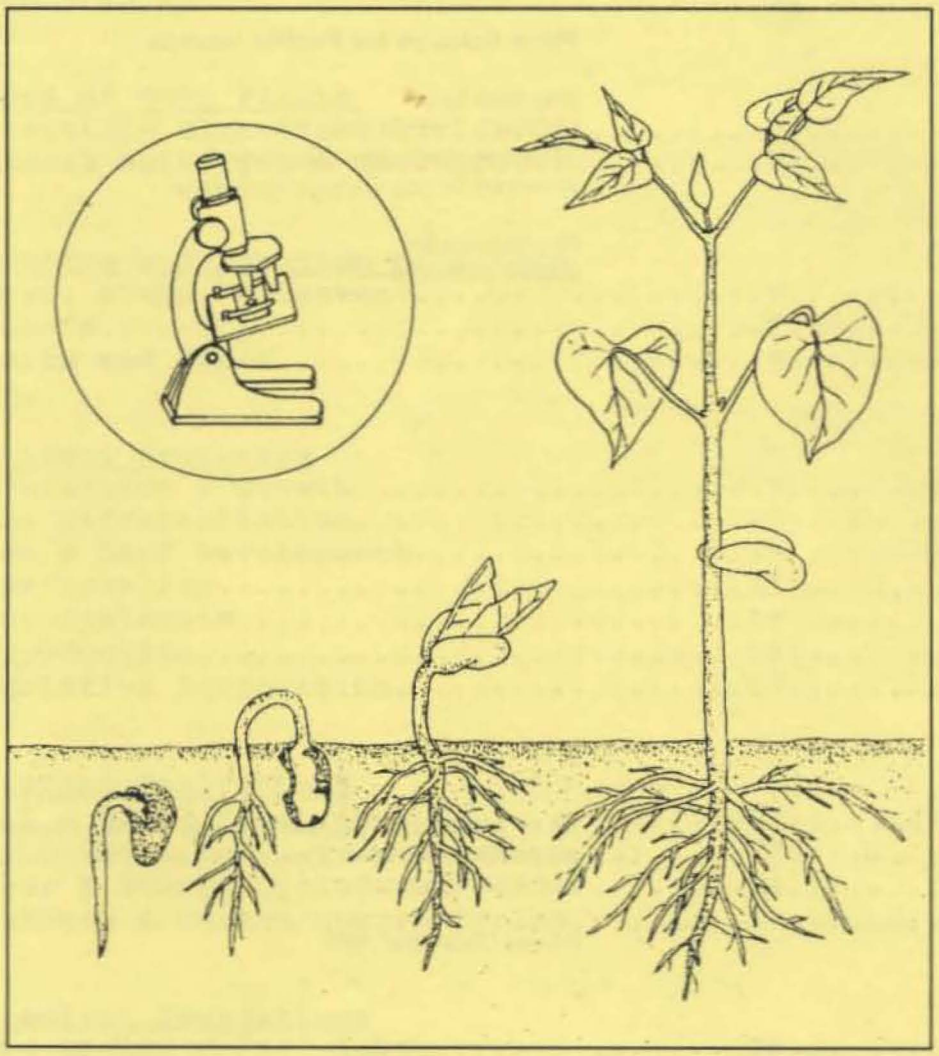
Agriculture Course Materials
ADAP 91–1

Plant Science
For Pacific Islands



ADAP
PROJECT
Agricultural Development in the American Pacific
Pacific Land Grant Programs

A publication of the Land Grant institutions of the Pacific:
American Samoa Community College, College of Micronesia, Northern Marianas Community College, University of Guam, and University of Hawai'i, through the Agricultural Development in the American Pacific (ADAP) Project. Funded through the US Department of Agriculture Cooperative Extension Service.

Plant Science for Pacific Islands

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Printed December 1991

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PLANT SCIENCE

For Pacific Islands

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INTRODUCTION

The following set of twenty two lecture notes are intended for use by Pacific Islands students wanting to learn the basic information about how plants grow. Understanding these basics is necessary to make the best use of practices which can increase plant production, give protection from pests, and make wise use of natural resources.

A strong emphasis is placed on definitions and identification. This knowledge is critical to students who will soon learn that the fields of science have a language, and languages, all their own. Learning the new vocabulary as well as the structure and function of plant parts are the prerequisite steps toward understanding complex botanical processes, scientific theories and laws.

These lectures have been developed and refined over numerous teaching semesters. They were then critically reviewed by professors of agronomy and horticulture at the University of Hawaii (UH) College of Tropical Agriculture and Human Resources. Finally, they were field tested through teaching at both the Micronesian Occupational College (MOC) in Belau, and the Community College of Micronesia (CCM) in Pohnpei.

I sincerely wish to thank Dr. Duane Bartholomew at UH, Dr. Joel Miles at MOC, and Dr. Reuben Dayritt at CCM for their efforts on this project. It will hopefully be the first of many teaching materials made available through the Pacific Land Grant institutions.

Plant Science
lecture 1

INTRODUCTION TO MAN AND PLANTS

Before man developed agricultural practices people were **FOOD GATHERERS.**

They collected wild plants, hunted animals, and caught fish.

- often hungry
- must keep moving / no permanent villages.

ex. in South America, Amazon indians; and Philippines, Tasadai tribe

Agriculture may have began when someone learned that seeds from eaten fruit would grow into plants. Later, people began to care for animals. When plants and/or animals are cared for close to homes or villages this is called **DOMESTICATION.**

TWO ADVANTAGES OF DOMESTIC AGRICULTURE WERE:

- allowed some control over the environment
- farmers could settle in one place

NOMADIC HERDSMAN are categorized between food gatherers / domesticators.

- maintain domestic animals
- roam open areas for grazing their livestock ex. Masai in Africa.

Early farming was at the level of **SUBSISTENCE AGRICULTURE**

- people grew just enough food for their family.

Pacific Island cultures are often said to be at this level.

What do you think? This is a good topic for class discussion.

In tropical areas early farming used **SHIFTING CULTIVATION.**

- people cleared an area of bush, farmed it until it was worn out, then moved to another place.

When land is cleared, farmed, abandoned to regrow, then used again (maybe 10 - 20 yrs. later) this is called **BUSH FALLOW.**

Farming which produces crops that are used for more than family food & clothing, but also for trade or sale is called **COMMERCIAL AGRICULTURE.**

- These things grown to sell are called **CASH CROPS.**

Commercial Agriculture has slowly developed into what might be called:

Modern Agriculture

Four major practices of Modern Agriculture are:

1. **MECHANIZATION** - the use of machinery on a large scale for land preparation, planting, cultivation, irrigation, harvesting, and processing. Essentially all agricultural activities.
2. **HYBRID PLANTS** - the development of crops for improved yields, climate adaption, disease resistance, etc.
3. **FERTILIZERS** the use of man made materials to improve soil.
4. **PESTICIDES** the use of man made chemicals to control weed, insect & disease problems.

These modern practices resulted in great increases of food production in developing countries during the 1960-70's known as the

" GREEN REVOLUTION ".

PROBLEMS ARISING FROM THE PRACTICES OF MODERN AGRICULTURE

1. **Mechanization** - Allowed for fast, easy land preparation
   ie. clearing and plowing.

   A. Many areas were planted to crops that should never have been plowed.
   ex. Approximately 6 million acres of land unsuitable for row crop agriculture in the Great Plains of the U.S. were planted in the 1920's and early 1930's.
   - This area is subject to reoccurring droughts and annual strong winds. The result was the Dust Bowl of 1933. From 2 to 12 inches of topsoil were lost to wind erosion.

   B. Highly mechanized agriculture requires large fields planted to a single crop, called **MONOCULTURE**. Pests, diseases, and soil erosion are all greater problems in a monoculture system.

   C. The larger amounts of pesticides, fertilizers and fuel needed require much more energy. These high levels of inputs result in higher yields which may not be sustainable.

   D. Mechanization has also allowed large forested areas to be cleared for livestock grazing. For example, in the Caribbean island of Haiti and the Amazon basin of South America have both suffered severe erosion due to deforestation for grazing.

2. **Hybrid Plants** - developed in the Green Revolution for high yields.

A. Most hybrid seed does not remain genetically pure in the second generation and must be repurchased for a future plantings.

B. The new high yielding varieties required the near-perfect conditions of modern agriculture for success:

i. Not too much or too little water,

ii. High soil fertility,

iii. Good pest control,

iv. Timeliness of operations.

C. Knowledge of these modern agricultural methods are unknown to the average farmer in developing countries.

3. **Fertilizers** - provide a fast short-term improvement in soil nutrients

A. As fertilizers became cheap and easily available, the use of manure and crop rotations were greatly reduced.

Crop plants which improve soil structure and fertility, such as deep rooted legumes (ex. alfalfa) were considered less important.

B. Fertilizers are most often applied only to add N,P,& K.

Micronutrients in the soil are used by plants but not replaced. This is sometimes called "mining" the soil of it's nutrients.

C. The soil chemistry can be further affected by fertilizer salts and acids. Extreme soil acidity and salt build up (under irrigation) can create conditions where many plants cannot grow.

4. **Pesticides** - Pest problems and pest control have existed as long as agriculture has been practiced.

A. Chemical pesticides generally kill off both pests and their natural predators. New pests can become a serious problem faster than predators return to the area.

B. Pests can build up a resistance to specific pesticides which are then no longer effective. **RESISTANCE** is the ability to be exposed to a dangerous substance without negative effects.

C. Chemical pesticides have been developed and used then later found to be serious risks to the health of man and animals.

For example, In 1940's, new forms of very powerful pesticides were developed which contain Chlorinated Hydrocarbons:

i. DDT is used for control of disease-bearing insects such as mosquitoes and fleas.

ii. 2,4-D, and 2,4,5-T are used for control of hard to destroy vegetation, such as Honolulu Rose. (Combined together these were called "Agent Orange" during the Vietnam War.)

In the 1950-60's it was realized that the substance, Dioxin, in these pesticides is not biodegradable and is stored in the fatty tissue of man and animals. The results of widespread use of these substances include many medical problems often related to improper application.

BIODEGRADABLE substance is able to be broken down into harmless substances relatively quickly by action of living things.

CURRENT TRENDS IN MODERN AGRICULTURE

Three major alternatives have developed in recent year as means to solve the problems arising from practices of modern agriculture:

1. **ORGANIC AGRICULTURE** is the use of only biological materials to keep the balance of nature in crop production systems. The philosophy of organic agriculture places highest importance on building and maintaining a very fertile soil, which has a high humus content.

   HUMUS is The dark colored, easily crumbled portion of the topsoil which comes from the total decomposition of living things.

   Four major practices of organic agriculture are :

   MULCH - Plant materials put on the soil surface. This practice controls weeds, holds moisture, and slowly builds humus.

   MANURE - Animal waste that is worked into the soil to add microorganisms and plant nutrients.

   COVER CROPS - (Green Manure) Deep rooted legume plants that are grown and turned into the soil for improving soil structure and fertility.

   COMPOST - The use of plant and animal materials to make humus under controlled conditions which include:

   A. The proper mixture of materials.
   B. The correct amount of water.
   C. Regular turning of the mixture.

2. **INTEGRATED PEST MANAGEMENT** (IPM) is the emphasis on Biological, Cultural and Mechanical controls to manage pest problems; with the use of Chemicals as a last alternative.

A. <u>Examples of Biological controls include</u>:

PREDATORS - an organism that eats a specific living thing as it's primary source of food.
ex. predator snails

PARASITES - a natural enemy of a specific pest which feeds on that pest while it is still alive.
ex. wasp that paratizes taro armyworm

PATHOGENS - diseases that infect insect pests but are not harmful to people.
ex. fungus that kills the Brontispa beetle of Coconut palms.

B. **CULTURAL CONTROLS** = The use of correct planting times, methods and locations to manage pest problems.

<u>Examples of Cultural Controls</u>:

- Crop Rotations
- Seasonal Plantings
- Attractant Plants

C. **MECHANICAL CONTROLS** = The use of physical pest control practices.

<u>Examples of Mechanical Controls</u>:

- Trapping Pests
- Search and Destroy
- Weed Removal

D. **CHEMICAL CONTROLS** = Pesticides are the last alternative choice.

3. **APPROPRIATE TECHNOLOGY** is the use of information, skills, tools, and machinery to match the needs of people to the biological environment of a specific area.

Appropriate Technology should meet the following criteria:

A. Low in cash costs.

B. Uses local materials whenever possible.

C. Creates jobs using local labor and skills rather than replacing them

D. Is on a small-scale that can be afforded by a village farmer or group of farmers.

E. Can be understood, controlled and maintained by people without a high level of education.

F. Uses renewable energy whenever possible.

Examples of appropriate technology include:

A. Solar Hot Water Heater

B. Gravity Irrigation Systems

C. Rotating Composting Bins

D. Agroforestry

E. Aquaculture/Farming Systems

F. Wind Powered Pumps

Plant Science
lecture 4

CLASSIFICATION OF CROP PLANTS

Two ways which scientific thought processes can be viewed are:

1) **CAUSAL;** meaning first there is a cause then an effect.

This can go on in a series of cause/effect, cause/effect...forever.

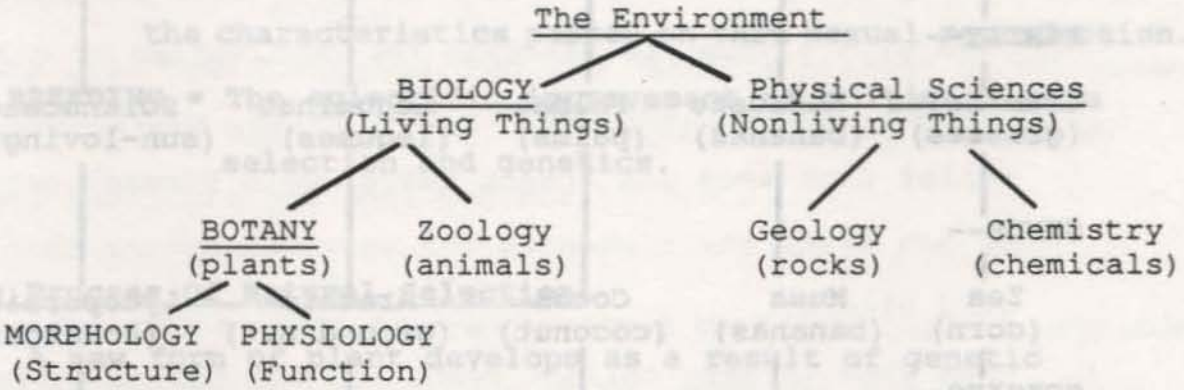
2) **DICHOTOMOUS;** meaning to divide ideas/objects into two smaller parts

This process of division can also go on forever.

It is dichotomous thinking which is used for scientific classification

SCIENTIFIC CLASSIFICATION is a system for arranging things or ideas into groups according to established measures.

ex. The classification of different fields of science:



BIOLOGY is the scientific study of living things.

BOTANY is the scientific study of plants.

PLANT MORPHOLOGY is the study of plant structure.

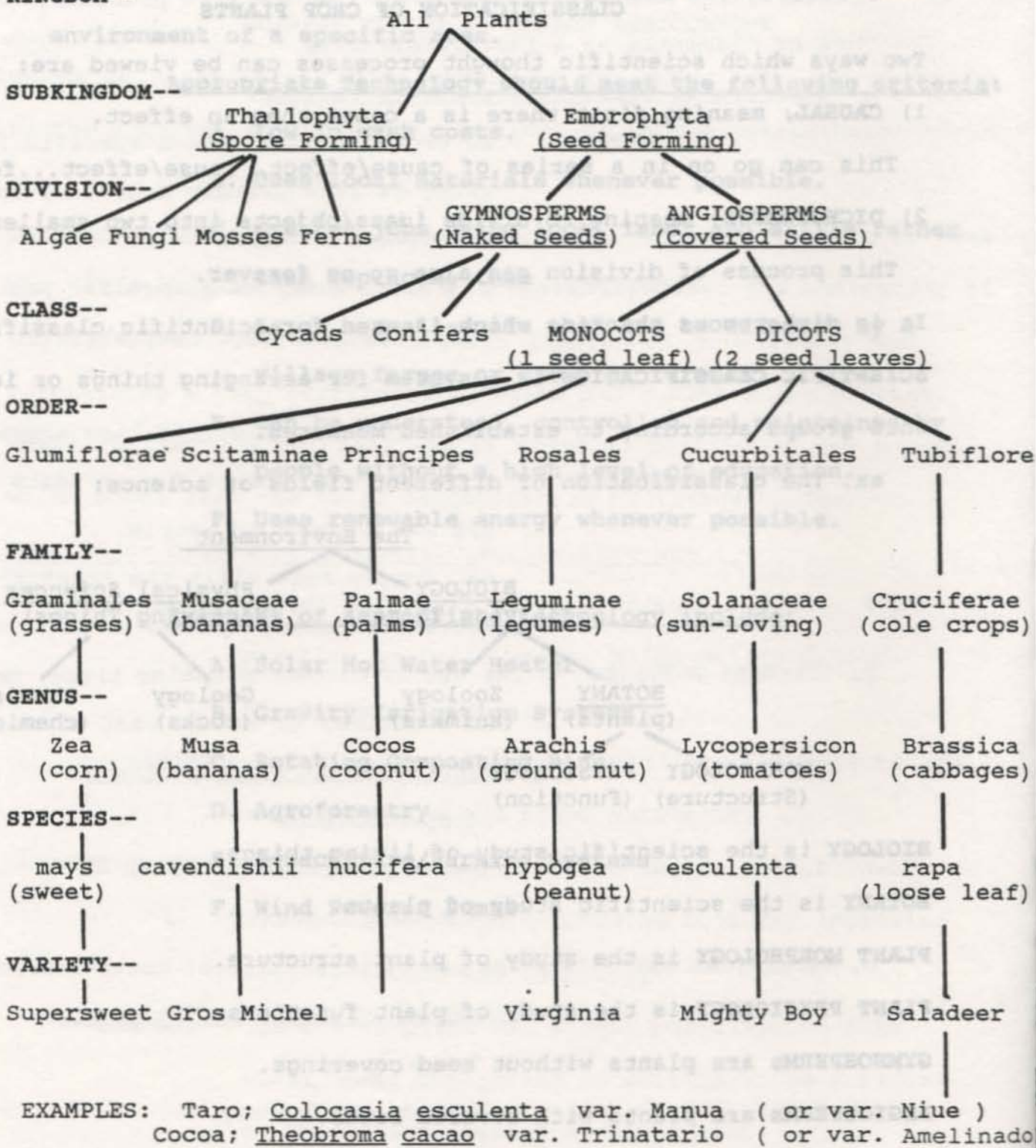
PLANT PHYSIOLOGY is the study of plant functions.

GYMNOSPERMs are plants without seed coverings.

ANGIOSPERMs are plants with covered seeds.

MONOCOTs are plants with one seed leaf.

DICOTs are plants with two seed leaves.



EXAMPLES: Taro; Colocasia esculenta var. Manua (or var. Niue)
Cocoa; Theobroma cacao var. Trinatario (or var. Amelinado

CLASSIFICATION OF CROP PLANTS (continued)

1. **Definitions**

SPECIES = A group of plants which can interbreed and are separate from all other species.

VARIETY = A named group of plants within a species which are identified by a set group of characteristics.

CULTIVAR = A cultivated variety; useful as crops or ornamentals.
- produced asexually from a single individual.
- produced sexually from seed which breeds true.

HYBRID = Produced sexually from seed that does not breed true.

MUTATION = Naturally ocurring physical or biochemical changes to the characteristics passed on thru sexual reproduction.

CROP BREEDING = The scientific improvement of cultivars thru selection and genetics.

2. **<u>The Process Of Natural Selection</u>:**

A. A new form of plant develops as a result of genetic recombination or mutation; which is either an advantage or disadvantage to survival in it's environment.

B. If it is a disadvantage, which is most common, the new form of plant or its offspring do not survive and the mutation is lost.

C. If it is an advantage, the new form survives and may replace its earlier unchanged form in future generations.

3. **An Example Of The Natural Selection Process**

A. A new plant occurs which has a different flower color; this may help, or hurt, it's ability to attract insects for pollination.

B. If it is a disadvantage and pollinators are not attracted the plant may not reproduce and the mutation is lost.

C. If it is an advantage the plant may reproduce in greater numbers and compete for water food and sunlight with plants having the earlier color.

4. **The Process Of Plant Selection by Humans:**

A. Wild plants are collected and eaten by Food Gatherers.

B. Some wild plants are **SELECTED** for cultivation by early farmers. These plants may receive water, nutrients, and relief from weed and insect pests. This **"domestication"** by man makes their chances for survival better than the wild plants.

C. When wise farmers collect seeds for the next planting, they **SELECT** the seeds from the largest fruit on the strongest, healthiest plants.

The human selection process is much faster than natural selection. Because of this many domesticated plants, such as corn or cabbage, exist only under cultivation.

5. **GENETICS** is the science of heredity and the study of ways physical and biochemical characteristics are passed to future generations.

Examples of how plant genetics can effect crop breeding:

i. Study the cross breeding of different varieties.

ii. Study the results of inbreeding a variety.

iii. Using man-made genetic mutations to create new varieties.

6. **A Cautionary Note:**

It has been discussed that new varieties which show advantages may replace older varieties. Similarily, when improved crop cultivars are introduced the old ones are often abandoned.

It has also been discussed that the "miracle plants" of the Green Revolution are high yielding, but require precise amounts of water, nutrients and pest control.

Therefore some scientists are concerned that widespread acceptance of these new cultivars in developing countries may replace the early varieties which are adapted to the local environment. For that reason plant breeders have begun growing and saving seeds of wild plants and local varieties that are not commercially important now, for a time in the future when they may be needed.

They also are including broader based types of resistance in new cultivars having recognized that a narrow based plants are highly susceptible to plant disease epidemics.

INTRODUCTION TO PLANT STRUCTURE AND FUNCTIONS

1. The Roots

A. The roots of a plant equal approximately 1/3 of the dry weight of an entire plant.

B. The three major functions of the root are:

ABSORPTION: Bringing up water and nutrients from the soil.

STORAGE: Holding starches, sugars, and moisture for plant use at a later time.

ANCHORAGE: Attaching and holding the plant in the soil.

C. Two forms of rooting systems; advantages and disadvantages:

TAP ROOT SYSTEM = A primary deep growing root.

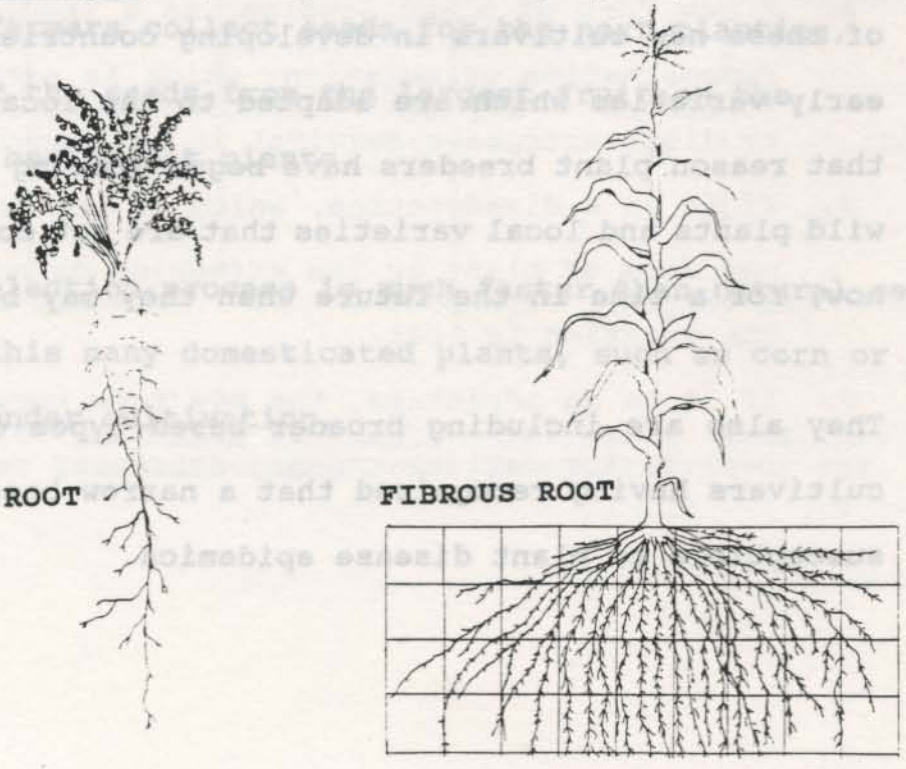
Advantages; 1) Drought resistant, 2) Strong anchorage

Disadvantage; 1) Slow response to fertilizers

FIBROUS ROOT SYSTEM = A network of smaller roots in the upper soil layers.

Advantage; 1) Quick response to fertilizers

Disadvantages: 1) Subject to drought, 2) Weak anchorage



TAP ROOT **FIBROUS ROOT**

2. The Shoot/Stem

A. The four major functions of the stem are:

SUPPORT: of leaves, flowers and Fruit.

TRANSFER: of plant nutrients and water from roots.
of starches and sugars from leaves.

PRODUCTION: of plant food through photosynthesis.

STORAGE: of water, starches and sugars, especially in modified stems.

B. Four forms of below ground stem modifications are:

BULB - has many layers, (ex. onion)

CORM - has nodes in a circular pattern, (ex. taro)

TUBER - has eyes in a random pattern, (ex. potato)

RHIZOME - runners which sprout leaves, (ex. many grass plants)

3. The Leaf

A. The three primary functions of a leaf are:

PHOTOSYNTHESIS: The use of sunlight to produce plant food.

TRANSPIRATION: The evaporative loss of water vapor.

RESPIRATION: The exchange of gasses (O_2& CO_2) necessary for photosynthesis.

B. The 4 major parts of a leaf are:

BLADE: The flat main body of the leaf.

PETIOLE: The base of the leaf connecting it to the stem.

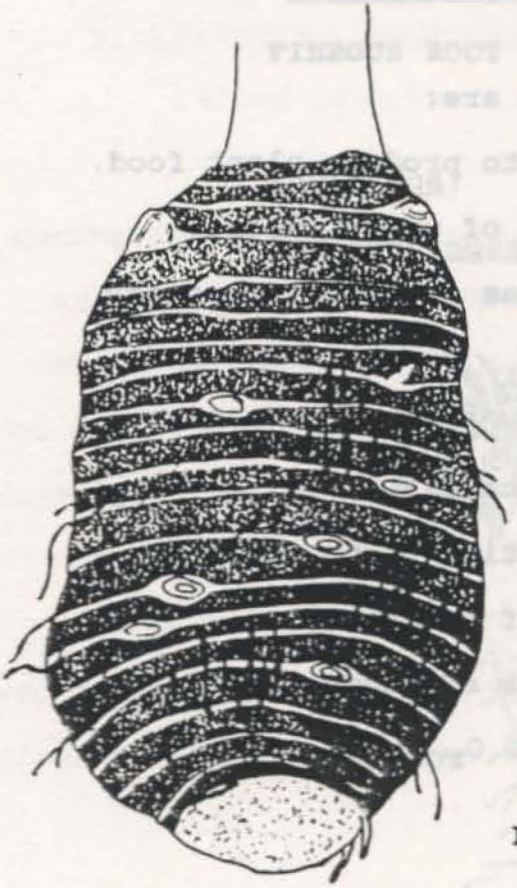
VEINS: The delivery system for leaf functions.

STOMATA: The microscopic openings for exchange gases including; CO_2, H_2O vapor, & O_2.

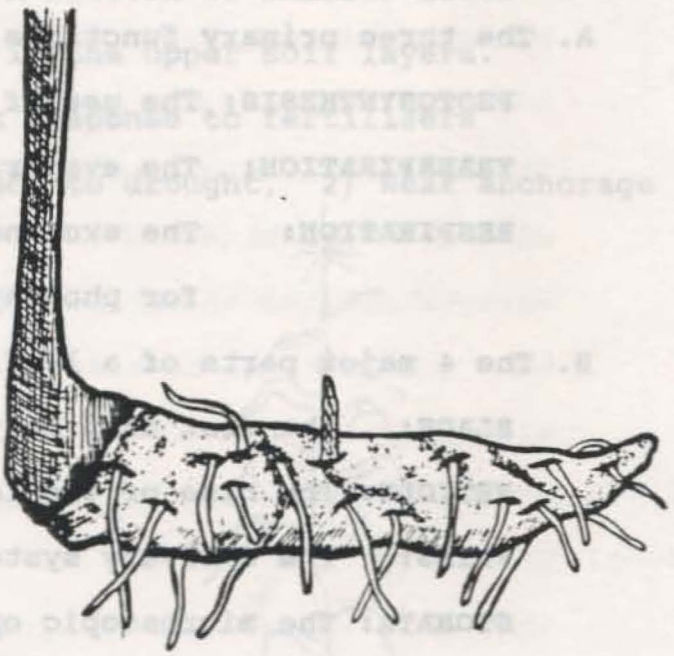
BULB (Onion)

TUBER (Potato)

CORM (Taro)



RHIZOME



FOUR FORMS OF BELOW GROUND STEM MODIFICATIONS

INTRODUCTION TO PLANT STRUCTURE AND FUNCTIONS (Continued)

1. The Flower Structure

It is important to know the names of flower parts, and to understand that the composite of some of these parts are given an additional name.

FLOWERS are the modified shoot/leaves of a seed bearing plant which contains the reproductive parts.

A. The **RECEPTACLE** is the modified part of the flower stem which supports all flower parts.

SEPALS are the modified leaves (usually green) which enclose the petals and protect the flower before it opens.

The **CALYX** is the name for all the sepals together

B. **PETALS** are the modified leaves (usually colored) which protect the reproductive flower parts and attract pollinating insects.

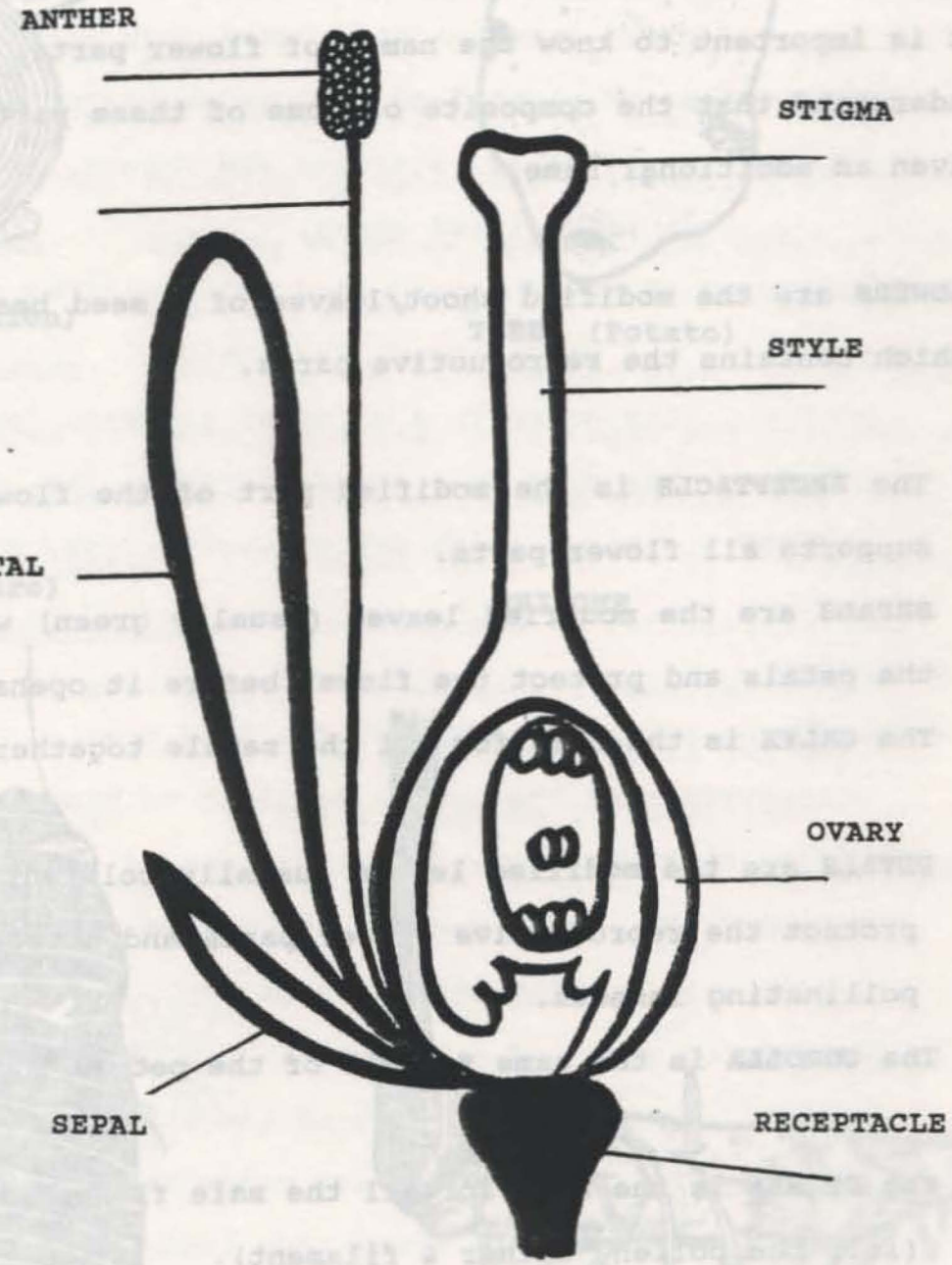
The **COROLLA** is the name for all of the petals together.

C. **The STAMEN** is the name for all the male flower parts together, (ie., the pollen, anther & filament).

POLLEN is the male "seed" in reproduction of angiosperms.

The **ANTHER** is the pollen producing/bearing part of the flower.

The **FILAMENT** is the slender stalk which holds the anther.



PARTS OF A FLOWER

D. The **PISTAL** is the name for all the female flower parts together, (ie., stigma, style, and ovary).

The **STIGMA** is the pollen receiving portion of the flower.

The **STYLE** is the stalk which holds the stigma and transfers pollen to the ovary.

The **CARPEL** is the stigma and style together.

The **OVARY** is the part where immature seeds are held before pollination and where mature seeds develop.

2. Flower/Plant Classification

A **COMPLETE** flower is made up of all flower parts.

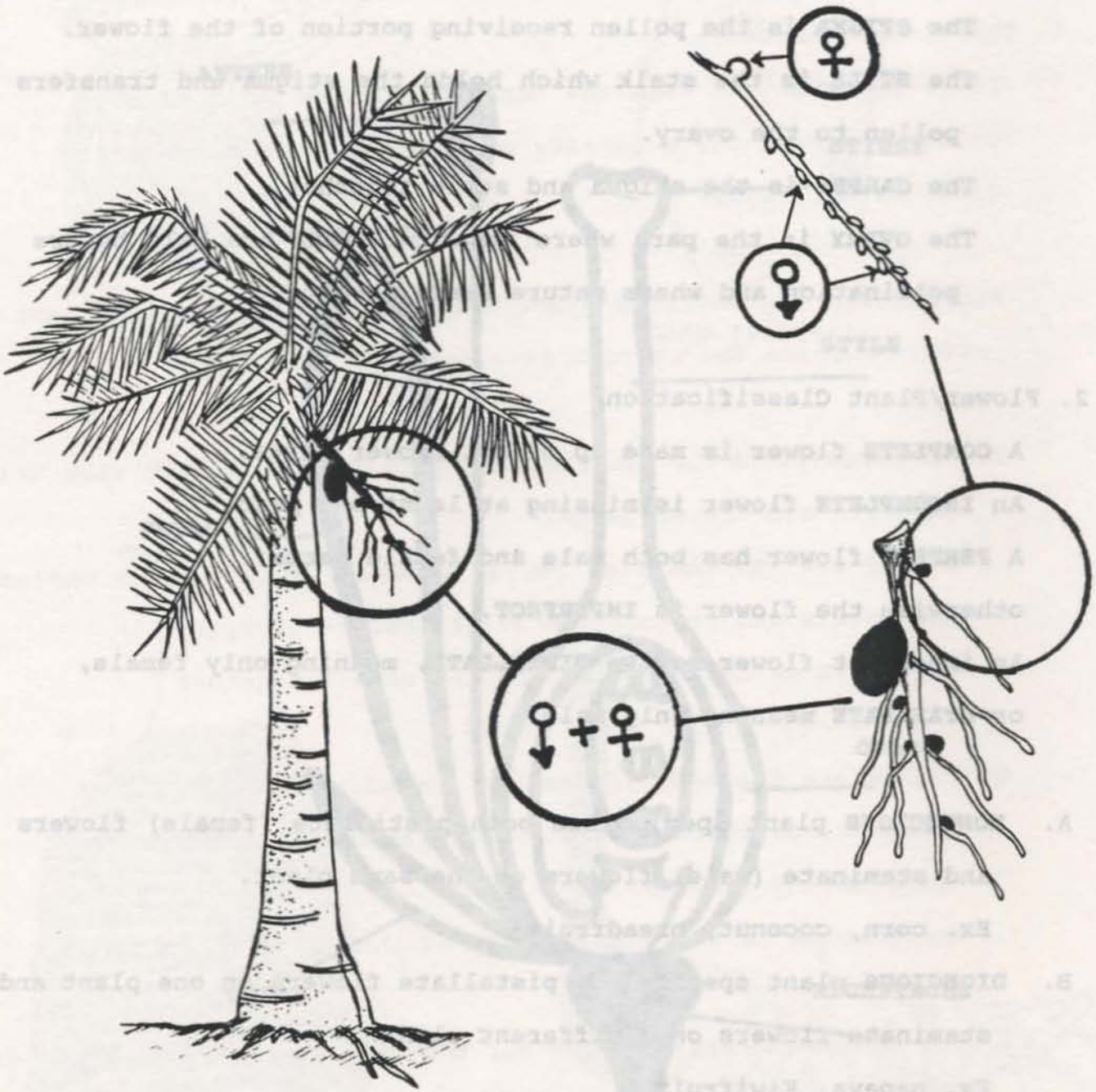
An **INCOMPLETE** flower is missing at least one part.

A **PERFECT** flower has both male and female parts; otherwise the flower is **IMPERFECT.**

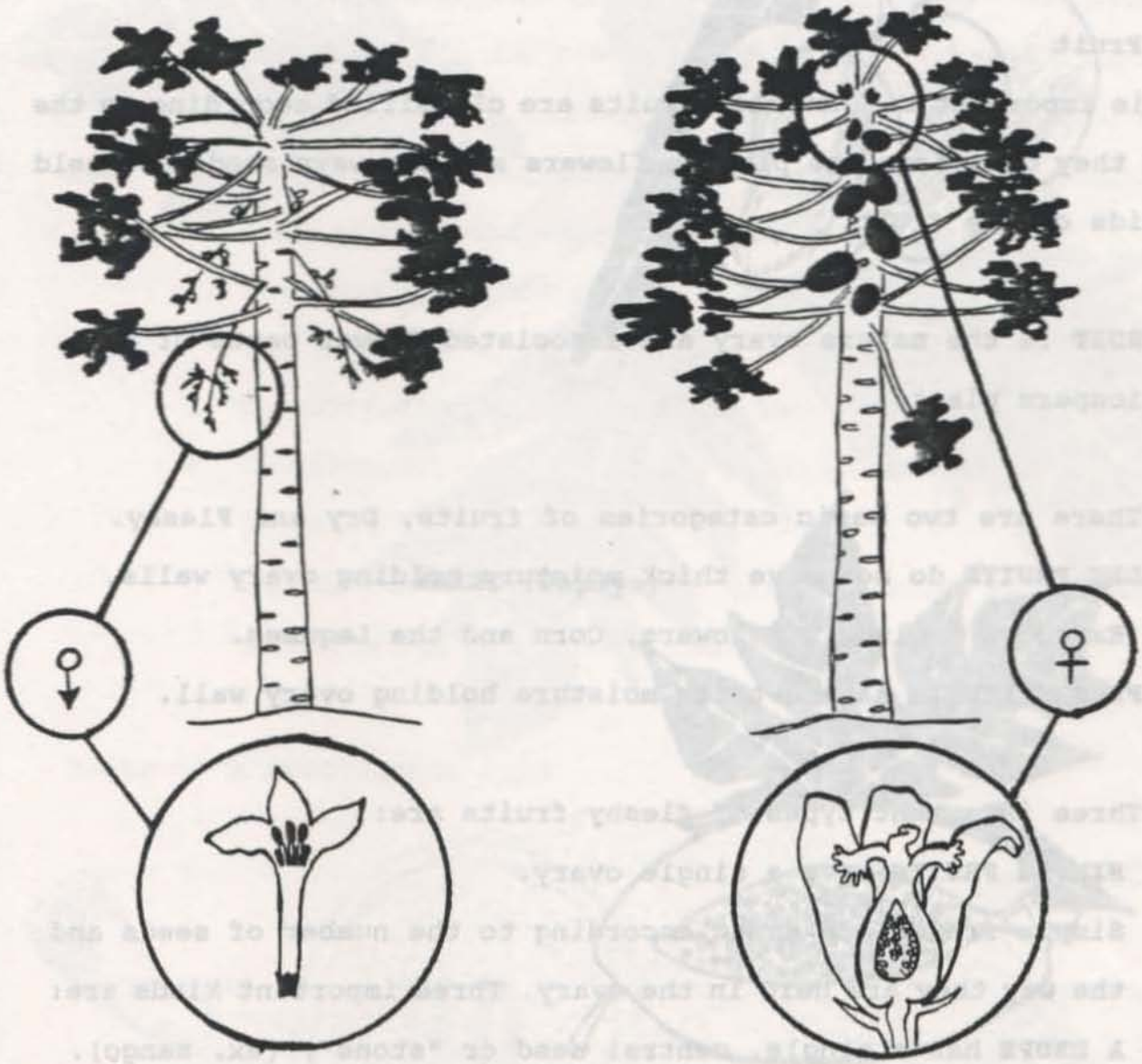
An imperfect flower may be **PISTILLATE**, meaning only female, or **STAMINATE** meaning only male.

A. **MONOECIOUS** plant species has both pistillate (female) flowers and staminate (male) flowers on the same plant.
Ex. corn, coconut, breadfruit.

B. **DIOECIOUS** plant species has pistallate flowers on one plant and staminate flowers on a different plant.
Ex. papaya, Kiwifruit.



A MONOECIOUS PLANT (Coconut)



A DIOECIOUS PLANT (Papaya)

INTRODUCTION TO PLANT STRUCTURE AND FUNCTIONS (Continued)

5. The Fruit

It is important to know that fruits are classified according to the way they grow from the plant's flowers and the ways seeds are held inside of the fruit.

A **FRUIT** is the mature ovary and associated flower parts of an angiosperm plant.

A. There are two basic categories of fruits, Dry and Fleshy.
DRY FRUITS do not have thick moisture holding ovary walls.
Examples include Sunflowers, Corn and the Legumes.
FLESHY FRUITS have a thick moisture holding ovary wall.

B. Three important types of fleshy fruits are:

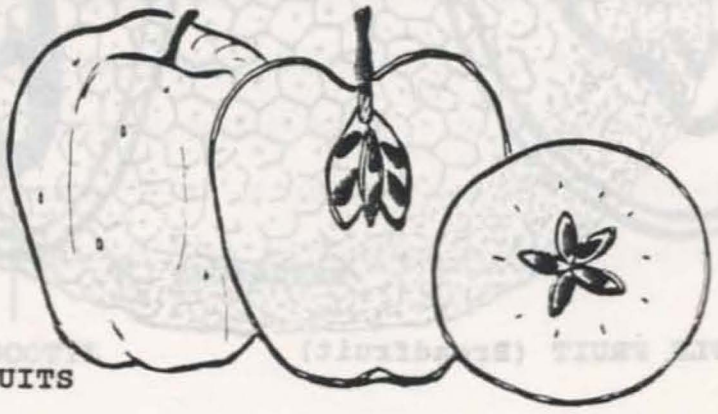
1. **SIMPLE FRUITS** have a single ovary.
Simple fruits are named according to the number of seeds and the way they are held in the ovary. Three important kinds are:
- A **DRUPE** has a single, central seed or "stone", (ex. mango).
- A **BERRY** has many seeds in a soft pulp, (ex. papaya and tomato).
- A **POME** has a hard central structure with many seeds (ex. apple)

2. **COMPOUND FRUITS** are produced from flowers with many carpels or pistils on a single receptacle, (ex. soursop and strawberry)
3. **MULTIPLE FRUITS** are the result of many separate but closely clustered flowers, (ex. pineapple and breadfruit).

DRUPE (Mango)

BERRY (Papaya)

POME (Apple)



THREE KINDS OF SIMPLE FRUITS

A MULTIPLE FRUIT (Breadfruit)

6. The Seed

A. A **SEED** is the fertilized and ripened ovule of a flowering plant capable of normal germination to produce a new plant.

B. The **TESTA** is the seed coat which protects the seed prior to germination and adsorbs moisture when germination begins.

C. The **ENDOSPERM** contains food for the germinating seedling in the form of carbohydrates, fats and oils.

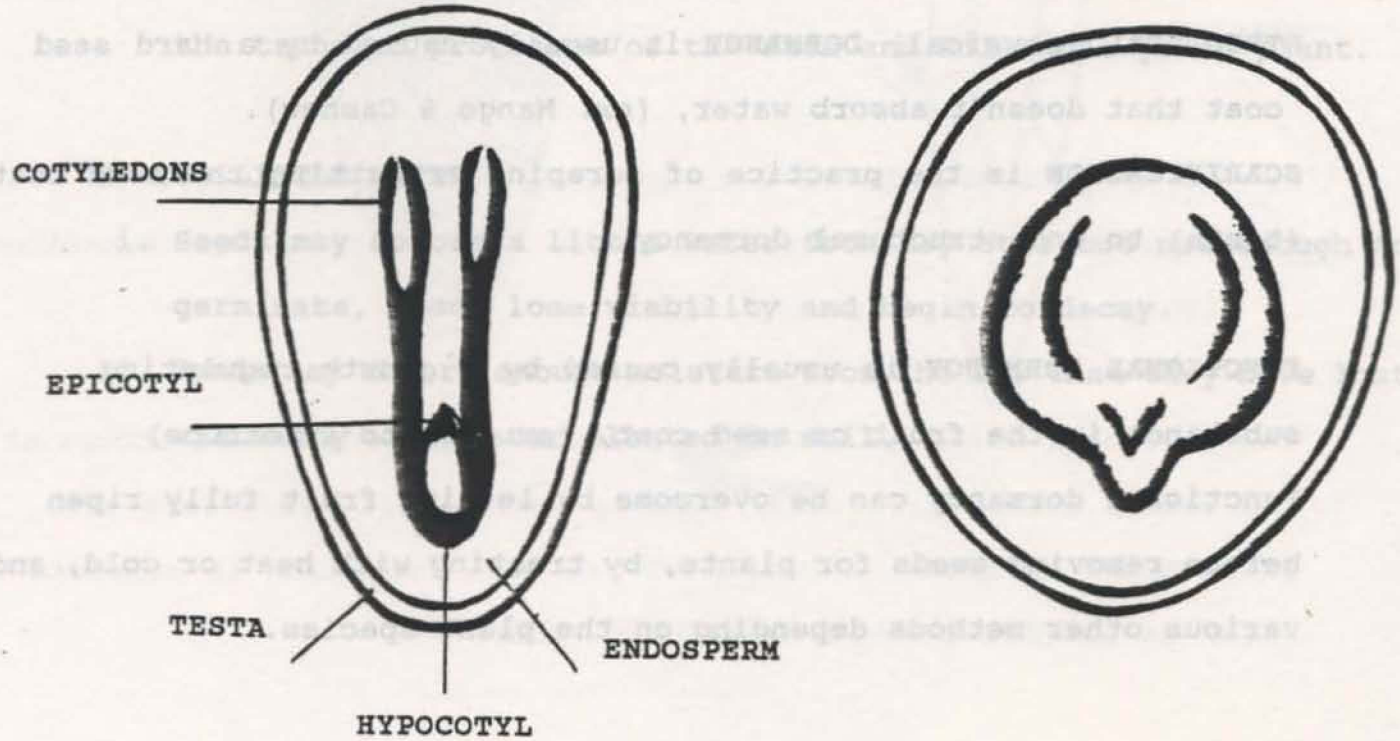
D. The **EMBRYO** is the potential seedling within a seed, including the cotyledons, epicotyl and hypocotyl.

E. The **COTYLEDON(S)** are the seed leave(s) of an embryo or seedling.

F. The **EPICOTYL** is the growing point of an embryo or seedling which is above the cotyledons.

G. The **HYPOCOTYL** is the lower growing point of an embryo or seedling which is below the cotyledons.

PARTS OF A DICOTYLEDON SEED



GERMINATION AND THE GROWTH OF A SEEDLING

1. **GERMINATION** is the growth of a seed's embryo to the point when it is self-sustaining.

Six Steps in the Germination process

1. The seed coat adsorbs water.
2. The cotyledons swell.
3. The root begins growth.
4. The shoot begins growth.
5. Cotyledons pull free of the testa.
6. Cotyledons/true leaves grow and make food.

VIABLE SEEDS are seeds able to germinate when given water and oxygen.

DORMANT SEEDS are viable but do not germinate under normal conditions because of structural or functional limitations.

STRUCTURAL (physical) **DORMANCY** is usually caused by a hard seed coat that doesn't absorb water, (ex. Mango & Cashew).

SCARIFICATION is the practice of scraping or cutting the seed coat (testa) to end structural dormancy.

FUNCTIONAL DORMANCY is usually caused by a growth regulating substance in the fruit or seed coat, (ex. Tomato & Lettuce) Functional dormancy can be overcome by letting fruit fully ripen before removing seeds for plants, by treating with heat or cold, and various other methods depending on the plant species.

2. Four Damaging Conditions For Seed Germination:

A. **IMPROPER PLANTING DEPTH -**

i. Too Deep - not enough stored food for the germinating embryo to reach the soil surface.

ii. Too Shallow - seeds can be washed away by rain or eaten by birds.

B. **OVER FERTILIZATION -**

i. High salt concentration from fertilizers can burn young roots;

ii. Salts can also kill the plant stem at the soil surface.

C. **SATURATED SOIL / POOR DRAINAGE -**

i. Seeds will rot from lack of oxygen in the soil.

ii. Soils that do not dry out provide conditions suited to disease.

DAMPING OFF is a fungal disease on the soil surface which stops the transfer processes of the stem and kills the young plant.

D. **TOO LITTLE WATER -**

i. Seeds may absorb a little water from dry soil but not enough to germinate, seeds lose viability and begin to decay.

ii. Seeds may absorb enough moisture from the air that they have lost viability when later planted in soil.

3. The Growth Process of a Seedling

A. The **ROOT CAP** is a protective cover for the root meristem as it grows down through the soil.

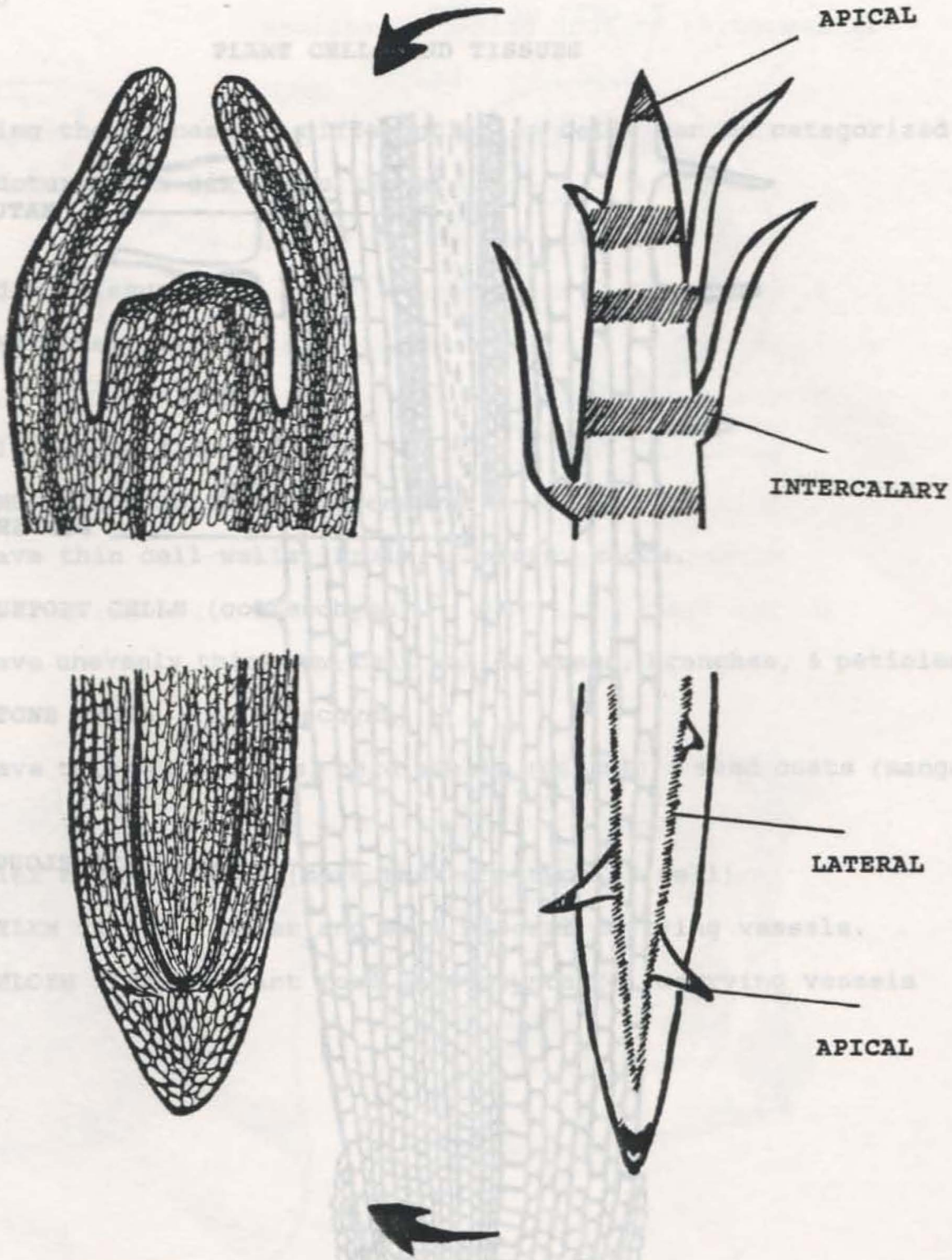
B. The **MERISTEM AREA** is a growing point where new plant cells are formed. Apical meristem areas are located at the tip of roots and stems. Plant cells are only formed at these localized and restricted areas of the root and shoot. (additional types of meristems; lateral, intercalary and the cambium layer will be discussed later.)

C. Newly formed plant cells in the meristem are very small and do not increase the actual plant size. The **CELL ELONGATION AREA** is the region behind the meristem where cells grow rapidly in size.

D. **DIFFERENTIATION** is the process of cells changing their structure for specific functions. The **DIFFERENTIATION AREA** is where these changes occur.

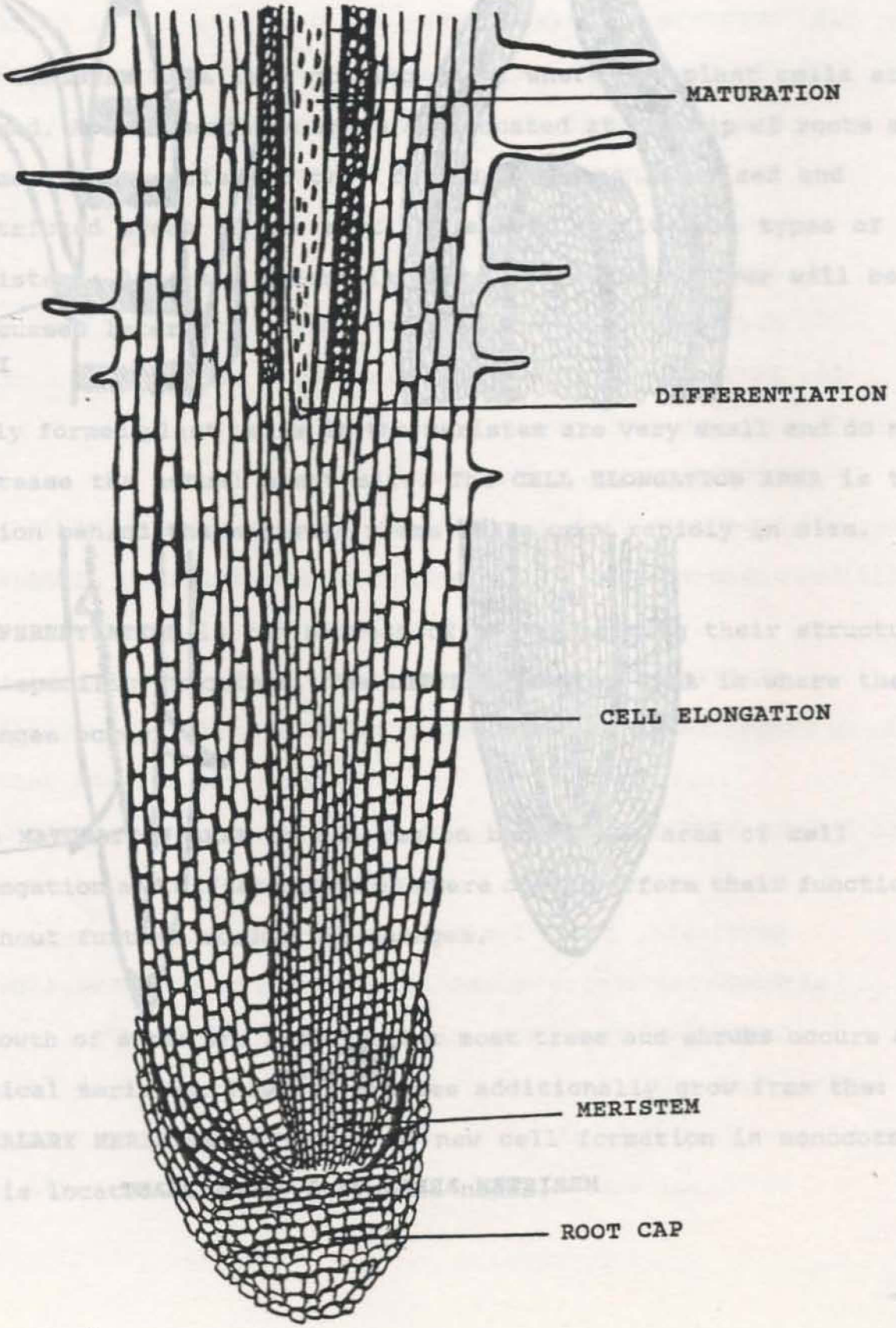
E. The **MATURATION AREA** is the region behind the area of cell elongation and differentiation where cells perform their functions without further structural changes.

The growth of stems and branches for most trees and shrubs occurs at the apical meristem, however grasses additionally grow from the: **INTERCALARY MERISTEM**, a region of new cell formation in monocots which is located slightly above the nodes.



MERISTEM AREAS OF A GRASS PLANT

CELLULAR AREAS OF A PLANT ROOT



Plant Science
Lecture 10

PLANT CELLS AND TISSUES

1. Following the process of differentiation cells can be categorized by structure into six basic types:

A. Dividing Tissue

1. Meristem cells

B. Simple Mature Tissue

2. **UNSPECIALIZED CELLS** (parenchyma) -
have thin cell walls; fruit, flowers, roots.
3. **SUPPORT CELLS** (collenchyma) -
have unevenly thickened cell walls; stems, branches, & petioles.
4. **STONE CELLS** (sclerenchyma) -
have thick cell walls; hard shells (peanut) & seed coats (mango)

C. Complex Mature Tissue (more than one type of cell)

5. **XYLEM TISSUE** - Water and soil mineral carrying vessels.
6. **PHLOEM TISSUE** -Plant food (photosynthate) carrying vessels

2. These structural cells and tissue are further categorized according to four primary functions:

A. The **EPIDERMIS** is the outer layer of a plant shoot and root. Functions include: protection, water absorption (root hairs), and water conservation (waxy coating).

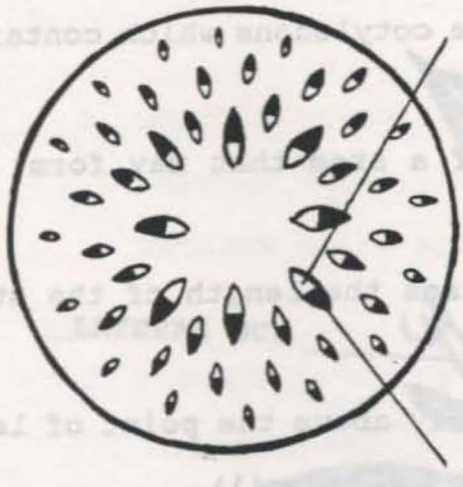
B. The **CORTEX** is the region between the vascular system and epidermis Functions include storage and protection.

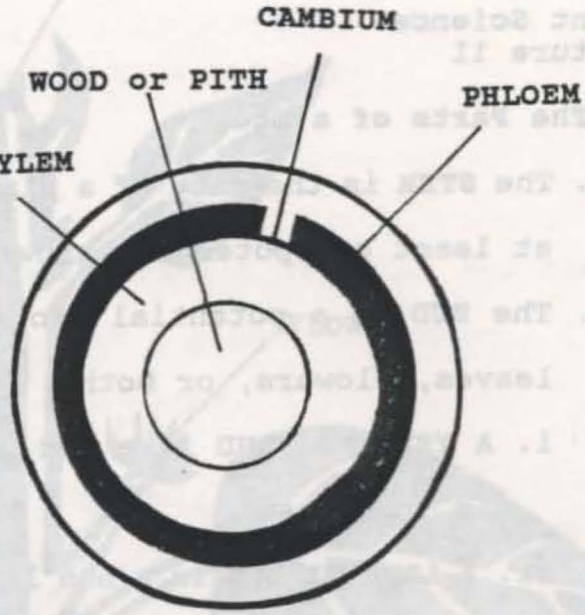
C. The **CAMBIUM** is the meristematic tissue within the stem which produces xylem and phloem.
This production of new xylem and phloem results in increased stem diameter, mostly from addition of xylem.

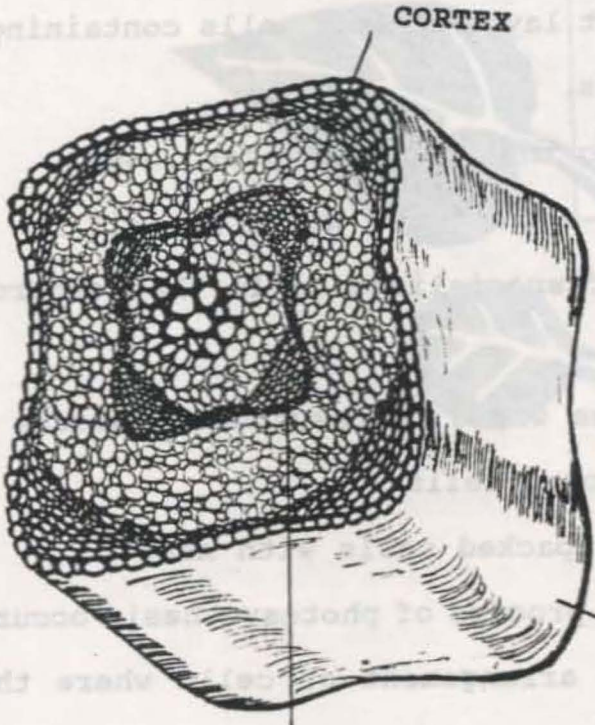
D. The **VASCULAR SYSTEM** contains the xylem and phloem arranged in rings (dicots) or bundles (monocots).

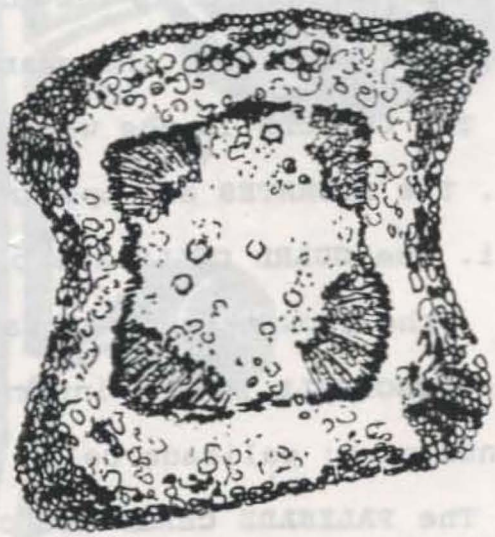
The epidermis, cortex and phloem are together commonly referred to as the BARK of a stem. The xylem in the center of a tree forms the WOOD and in younger stems may be called the PITH.

PLANT STEM TISSUES









Plant Science
Lecture 11

1. The Parts of a Stem.

A. The **STEM** is the part of a plant above the cotyledons which contains at least one potential growing point.

B. The **BUD** is a potential growing point of a stem that may form; leaves, flowers, or both.

i. A **TERMINAL BUD** is a bud which increases the length of the stem as it grows.

ii. A **LATERAL BUD** is a bud located directly above the point of leaf attachment to the stem (i.e., in the leaf axil).

C. The **LEAF AXIL** is the point above where the petiole joins the stem.

D. The **LEAF NODE** is the point of leaf attachment to the stem.

E. The **INTERNODE** is the area between the leaf nodes on the stem.

2. The Functional Parts of The Leaf.

A. The **LEAF EPIDERMIS** is the outermost layer of leaf cells containing; cuticle, stomates, and guard cells.

i. The **CUTICLE** is the waxy coating that reduces water loss.

ii. **The STOMATES** are openings for exchange of water and air.

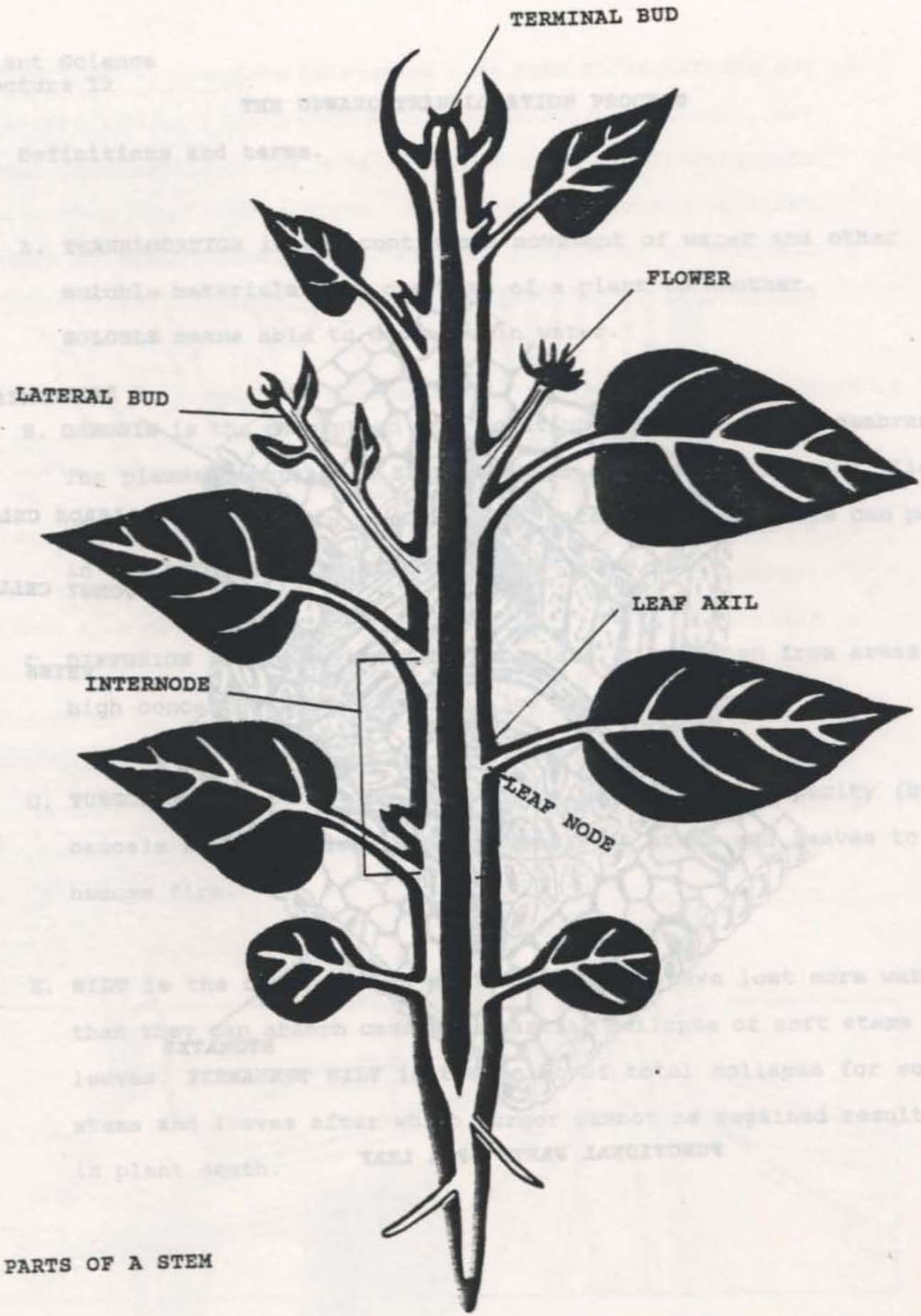
iii. The **GUARD CELLS** are pairs of specialized cells that control the flow through stomates.

B. The **MESOPHYLL** is the internal area where photosynthesis occurs containing; palisade cells and spongy cells.

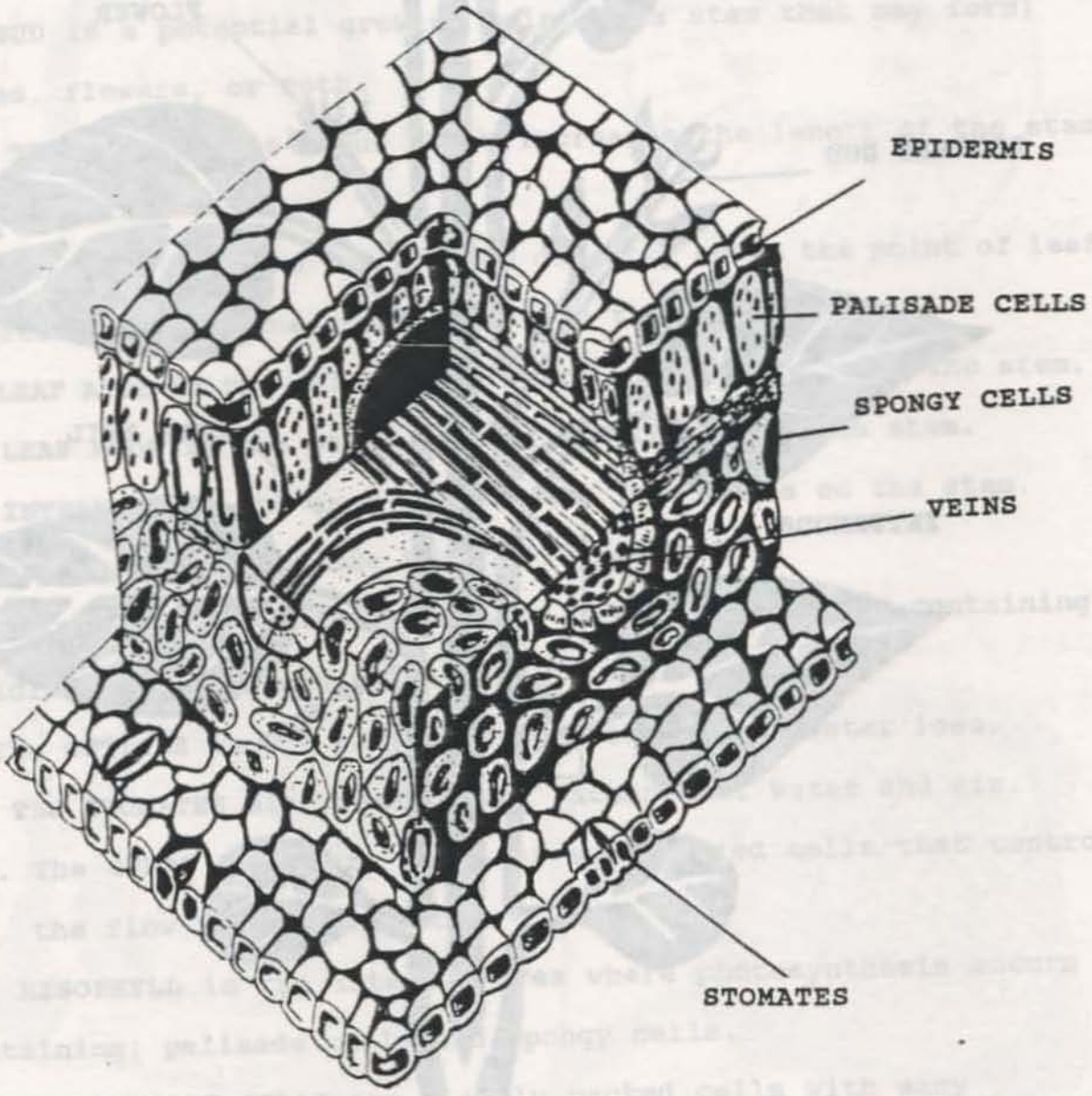
i. The **PALISADE CELLS** are closely packed cells with many chloroplasts where the chemical process of photosynthesis occurs

ii. The **SPONGY CELLS** are A loose arrangement of cells where the exchange of air and water occurs.

C. The **VEINS** are the vascular tissue containing xylem and phloem.



PARTS OF A STEM



FUNCTIONAL PARTS OF A LEAF

Plant Science
Lecture 12

THE UPWARD TRANSLOCATION PROCESS

1. Definitions and terms.

A. **TRANSLOCATION** is the continuous movement of water and other soluble materials from one part of a plant to another. **SOLUBLE** means able to dissolve in water.

B. **OSMOSIS** is the absorption of a solution thru cell plasma membrane. The plasma membrane is **SEMIPERMEABLE**. That means it only allows certain materials to pass through. Water & some minerals can pass in but not sugar and starches cannot pass out.

C. **DIFFUSION** is the movement of materials in solution from areas of high concentration to areas of low concentration.

D. **TURGOR** is the condition of plant cells filled to capacity (by osmosis and diffusion) which causes soft stems and leaves to become firm.

E. **WILT** is the condition of plant cells that have lost more water than they can absorb causing a partial collapse of soft stems and leaves. **PERMANENT WILT** is the point of total collapse for soft stems and leaves after which turgor cannot be regained resulting in plant death.

F. The **TRANSPIRATION RATE** is a measure of evaporative loss over time. (ex., The transpiration rate of a corn plant equals 2 quarts/day.) Transpiration rate is a result of plant structure (thickness of cuticle, number of stomates) and environment (temp. and humidity).

G. **ADHESION** is attraction of water molecules to walls of container. **COHESION** is an attraction of water molecules to each other.

2. Five Steps In The Upward Translocation Of Water.

A. Water and mineral solution is absorbed by roots as a result of osmosis and diffusion.

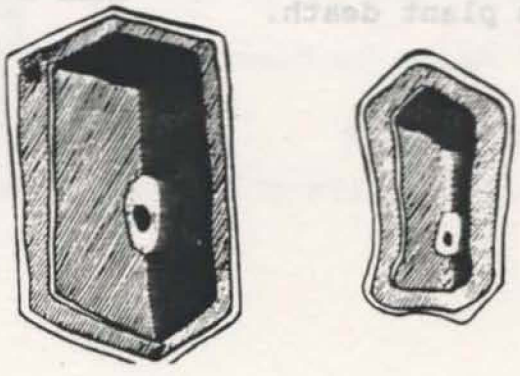
B. At night, root cells become turgid and create pressure which forces the water/mineral solution into the plant stem.

C. Adhesion and cohesion of water in xylem vessels forms a continuous "chain" of solution.

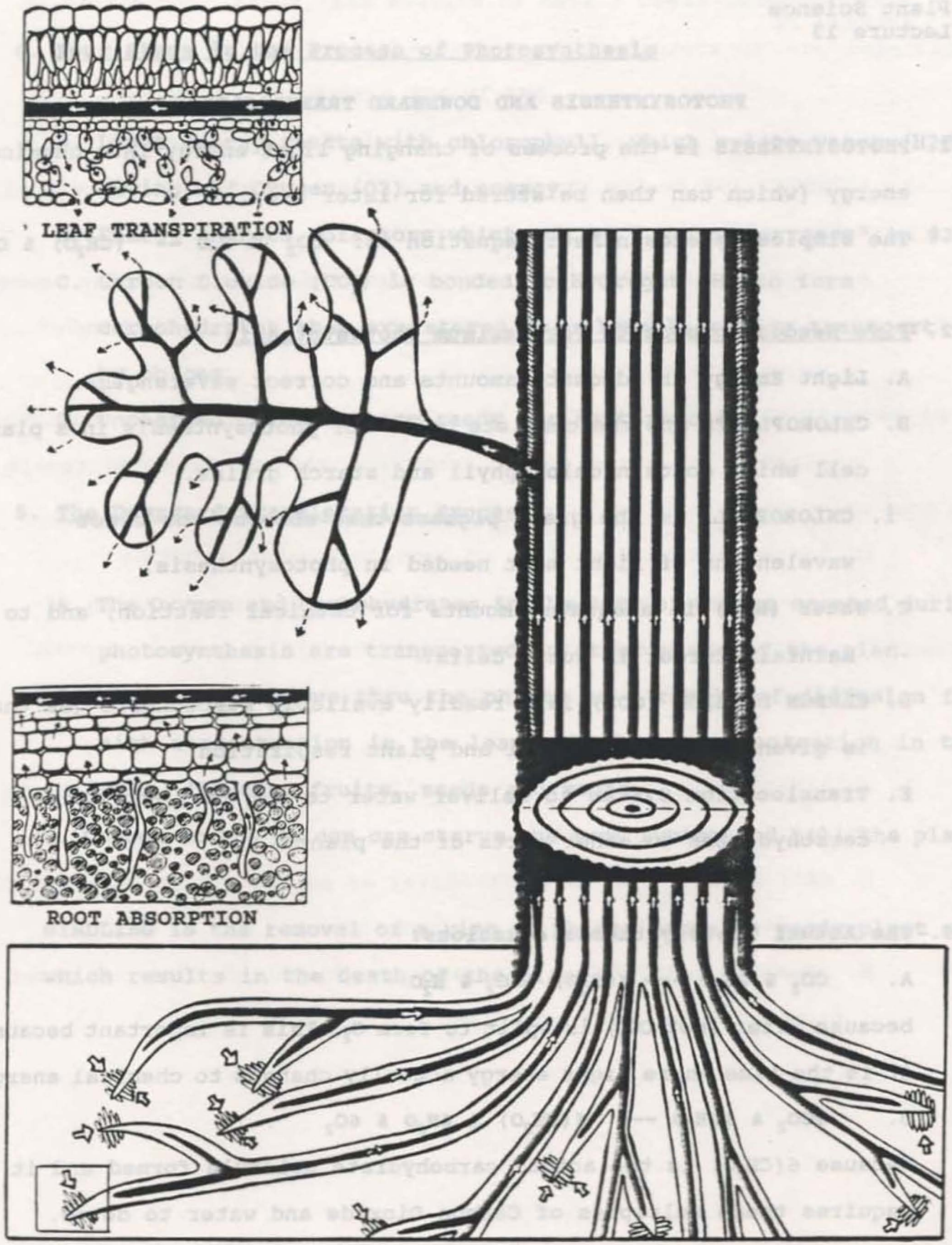
D. During the day, transpiration pulls the "chain" of solution up to the leaves.

E. Water is lost to the environment by evaporation thru stomates and epidermis of the leaves.

TURGOR and WILT



THE UPWARD TRANSLOCATION PROCESS



PHOTOSYNTHESIS AND DOWNWARD TRANSLOCATION

1. **PHOTOSYNTHESIS** is the process of changing light energy into chemical energy (which can then be stored for later use).

   The simplest photosynthetic equation is: CO_2 & H_2O -- (CH_2O) & O_2

2. **Five Needed Components For Maximum Photosynthesis**

   A. **Light Energy** in adequate amounts and correct wavelengths.

   B. **CHLOROPLASTS** are the complete units for photosynthesis in a plant cell which contain chlorophyll and starch grains.

      i. **CHLOROPHYLL** is the green pigment that absorbs the exact wavelengths of light most needed in photosynthesis.

   C. **Water (H2O)** in adequate amounts for chemical reaction, and to maintain turgor in guard cells.

   D. **CARBON DIOXIDE (CO2)** is a readily available atmospheric gas that is given off during animal and plant respiration.

   E. **Translocation System** to deliver water to the leaf and carry carbohydrates to other parts of the plant.

3. **The Actual Photosynthesis equations:**

   A. CO_2 & $2H_2O$ --- (CH_2O) & O_2 & H_2O

   because water (not CO_2) is split to form O_2. This is important because it is the time where light energy actually changes to chemical energy

   B. $6CO_2$ & $12H_2O$ --- $6(CH_2O)$ & $6H_2O$ & $6O_2$

   because $6(CH_2O)$ is the actual carbohydrate molecule formed and it requires these multiples of Carbon Dioxide and water to do so.

4. **Four Steps in the Process of Photosynthesis**

A. Light energy reacts with chlorophyll, which splits water (H2O) giving off Oxygen (O2) and energy.

B. Energy charges cofactors which act as "energy currency" in #3.

C. Carbon Dioxide (CO_2) is bonded to Hydrogen (H) to form carbohydrates that are stored in chloroplasts for transport by phloem.

D. Uncharged cofactors are ready for next reaction.

5. **The Downward Translocation Process**

A. The Oxygen and Carbohydrates in the form of sugars created during photosynthesis are transported to other parts of the plan.

B. These sugars move thru the phloem as a result of diffusion from high concentration in the leaves to lower concentration in the stem, flowers, fruits, seeds and roots.

C. Damage to the phloem can starve the root system and kill the plant.

GIRDLING is the removal of a ring of phloem around a woody plant stem which results in the death of the plant.

Plant Science
Lecture 14

SEX IN THE GARDEN

1. **REPRODUCTION** is the process of replication for both individual cells and entire organisms.
   A. **ASEXUAL REPRODUCTION** is the process which increases the number of plants thru regular cell division and differentiation of vegetative (nonsexual) parts.
   B. **SEXUAL REPRODUCTION** is the process which increases the number of plants thru seeds formed from the union of male and female sex cells.
   C. Advantages of Each Type of Reproduction
      i. Asexual Reproduction results in exact duplication of parent plant characteristics.
      ii. Sexual Reproduction can result in new varieties.

2. **POLLINATION** is the transfer of pollen from the anther (male) to the stigma (female) of a flower.
   A. **SELF-POLLINATION** is the transfer of pollen within the same flower or different flowers of the same plant.
   B. **CROSS-POLLINATION** is the transfer of pollen from one plant to a flower from a different plant.

3. **Structure, Causes, and Results of Self / Cross Pollination**

A. Self-pollinated plants have perfect flowers or are imperfect monoecious plants.

B. Cross-pollinated plants may be perfect or imperfect, monoecious or dioecious.

C. Self-pollination can be caused by gravity (pollen falls on flowers below) and/or contact between flower parts.

D. Cross-pollination can be caused by wind, insects, birds, animals or people.

E. Self-pollination results in a high degree of uniformity in the next generation.

F. Cross-pollination results in a mixture of the qualities from both parent plants.

Characteristics to attract pollinators include; color, odor, and nectar. Wind pollinated plants usually produce large amounts of pollen.

VEGETATIVE PROPAGATION

VEGETATIVE PROPAGATION is the production of new plants using their ability to regrow from specific nonsexual parts.

THREE METHODS OF VEGETATIVE PROPAGATION

1. **Use of special plant parts -**
   A. **Offshoots** (ex., banana suckers and pineapple suckers).
   B. **Modified stems** (ex., taro corms and yam tubers).
   C. **Leaves** (ex. ornamental plants; begonia and african violet).
2. **Growing roots on specific plant parts -**
   A. **CUTTINGS** are a specific plant part that is separated from the parent plant for the purpose of rooting to grow a new plant.

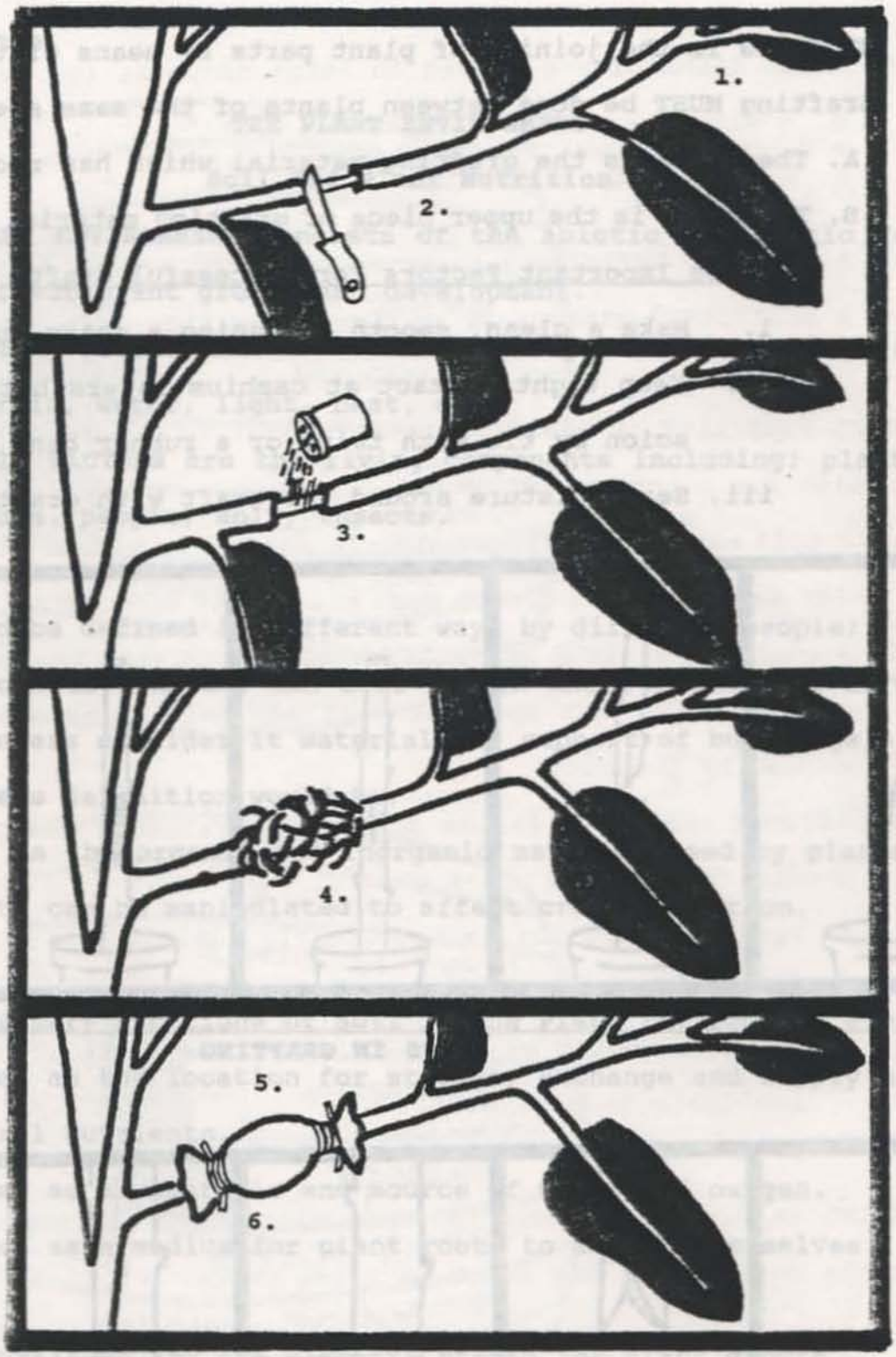
      Four Steps To Make a Cutting

      i. Make a smooth clean cut
      ii. Allow thick cuttings to dry
      iii. Apply rooting hormone
      iv. Set into well drained rooting medium

   B. **LAYERING** is the method of growing roots on a plant part that has been girdled but not removed from the parent plant.

      Six Steps To Make An Air Layer

      i. Select a healthy branch (must be hardwood / dicot)
      ii. Scrape away the bark and cambium
      iii. Cover the scraped area with rooting hormone
      iv. Apply wet material (moss) around scraped area
      v. Wrap with plastic
      vi. Tie tightly (wet material should not dry out, but too much water will cause rotting).



STEPS IN MAKING AN AIR LAYER

3. **GRAFTING** is the joining of plant parts by means of tissue growth. Grafting MUST be done between plants of the same species.

A. The **STOCK** is the grafting material which has roots.

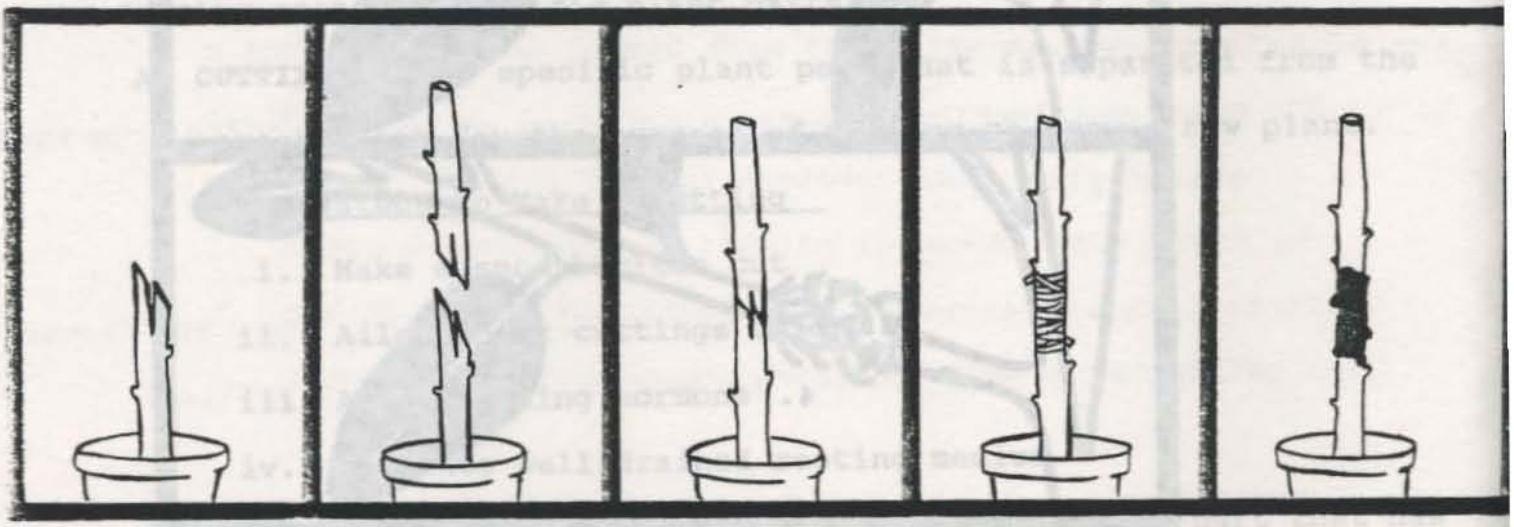
B. The **SCION** is the upper piece of grafting material (without roots)

Three Important Factors For Successful Grafts

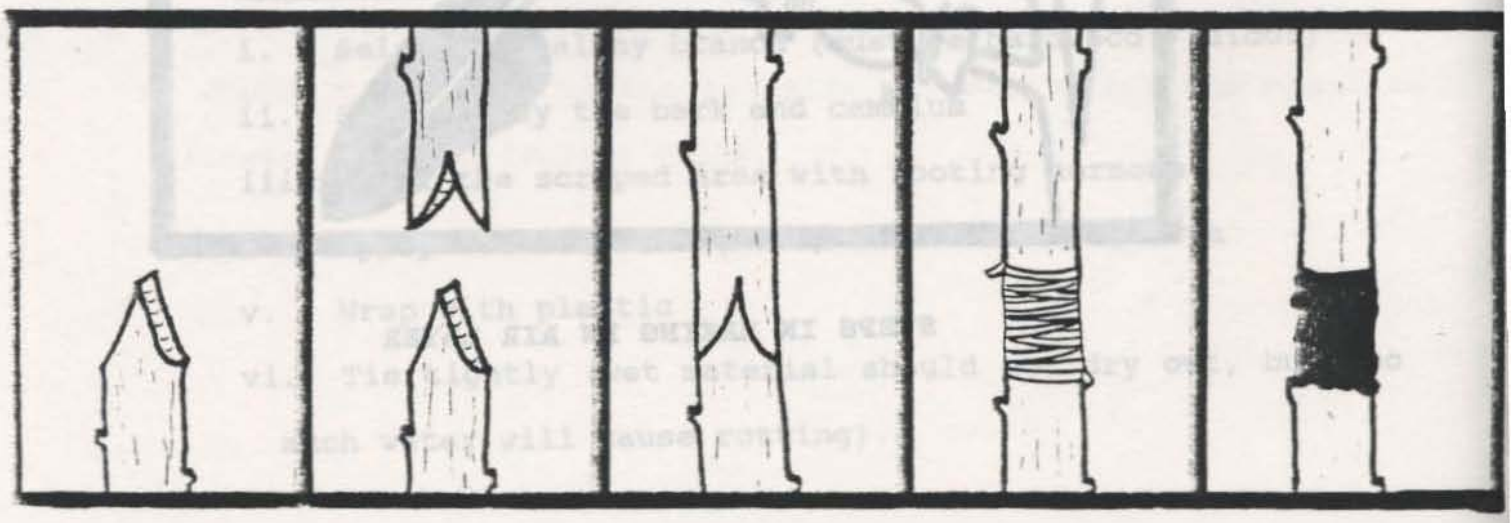
i. Make a clean, smooth cut using a sharp knife.

ii. Keep tight contact at cambium layers between stock and scion by tie with twine or a rubber band.

iii. Seal moisture around the graft with grafting wax.



STEPS IN GRAFTING



THE PLANT ENVIRONMENT

Soil And Plant Nutrition

1. The **PLANT ENVIRONMENT** consists of the abiotic and biotic factors which affect plant growth and development.

   B. **ABIOTIC FACTORS are the nonliving components including,** soil, minerals, water, light, heat, air.

   A. **BIOTIC FACTORS** are the living components including; plants, animals, people, soil, insects.

2. Soil can be defined in different ways by different people:

   A. Geologists consider the soil a thin shell around the earth and engineers consider it material for support of buildings & roads.

   B. Farmers definition would be;
   SOIL is the organic and inorganic material used by plants for growth can be manipulated to affect crop production.

3. <u>Three Primary Functions of Soil in The Plant Environment are:</u>

   A. Serves as the location for storage, exchange and supply of mineral nutrients.

   B. Serves as a reservoir and source of water and oxygen.

   C. Serves as a medium for plant roots to anchor themselves.

4. **PLANT NUTRIENTS** are the elements needed for plant growth.

   A. **MICRO ELEMENTS** are needed in small amounts, (parts per million).

Fe = Iron	B = Boron	Mn = Manganese	Z = Zinc
Mo = Molybdenum	Cu = Copper	Cl = Chlorine	

B. **MACRO ELEMENTS** are needed in large amounts, (parts per hundred).

N = Nitrogen	Ca = Calcium
P = Phosphorous	Mg = Magnesium
K = Potassium	S = Sulphur

C. A **NUTRIENT DEFICIENCY** is a severe shortage of any needed element.

D. A **DEFICIENCY SYMPTOM** is an observable sign of nutrient shortage.

5. **SOIL FERTILITY** is the ability of a soil to provide nutrients needed for plant growth.

A. A soil has **LOW FERTILITY** when it does not contain enough nutrients for maximum plant growth Some plants may show deficiency symptoms.

B. A soil has **MAXIMUM FERTILITY** when it contains the greatest amount of nutrients that specific soil may hold. Some plants may be killed by toxicity.

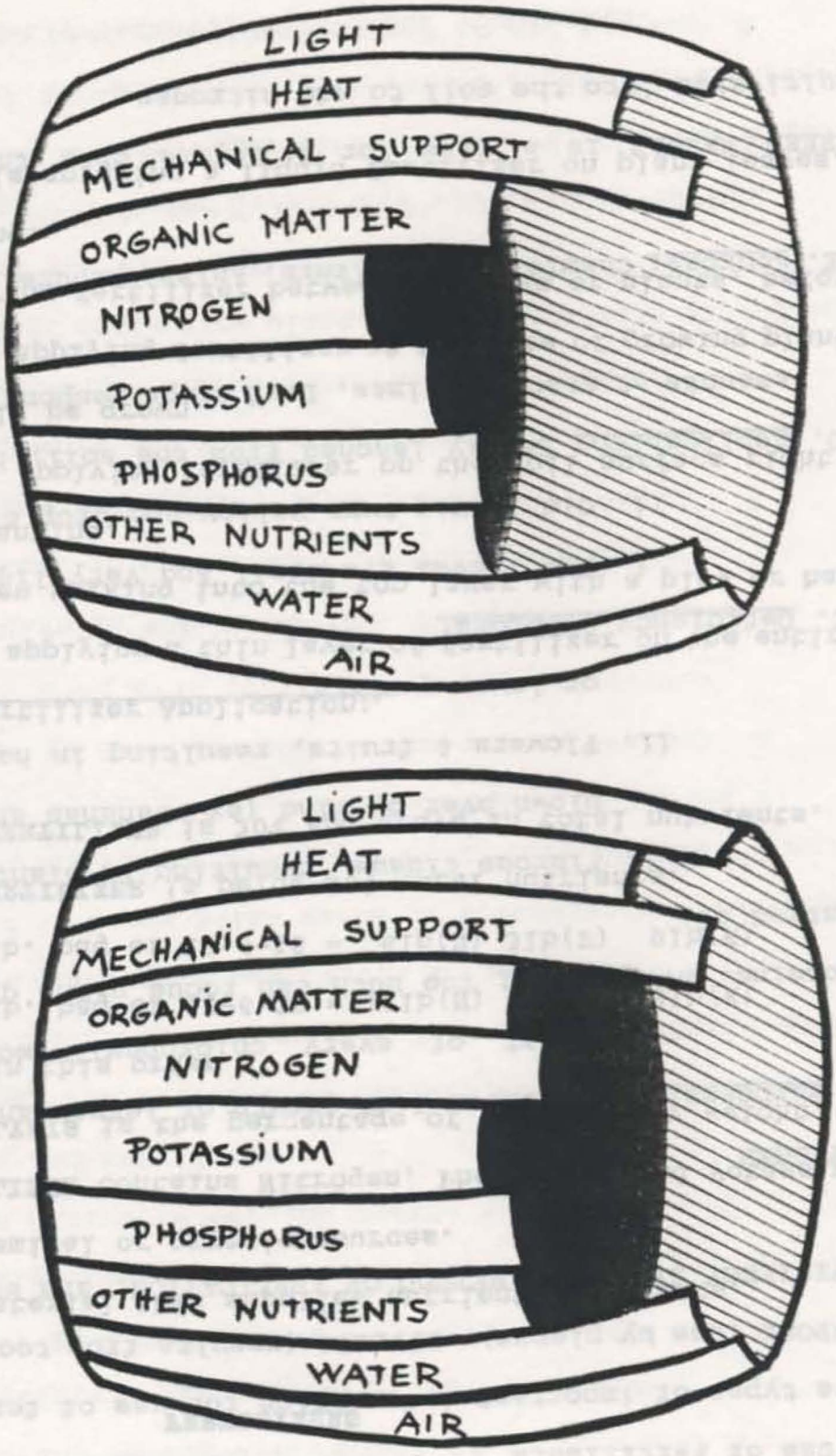
C. **OPTIMUM FERTILITY** is the amount of available plant nutrients needed for maximum plant growth.

** Optimum fertility is not usually achieved in one quick step. When large amounts of fertilizer are applied at one time much of it is wasted by leaching or is tied up in a form that is not available to plants.

LEACHING is the loss of nutrients in solution by downward movement thru the soil beyond the reach of plant roots.

THE LAW OF THE LIMITING FACTORS:

Plant growth can be no greater than the limit created by a needed element which is in shortest supply.



THE LAW OF LIMITING FACTORS

FERTILIZERS

1. **FERTILIZER** is a material that supplies nutrients to plants.
   It can be from chemical or organic sources.
   A. **COMPLETE FERTILIZER** contains Nitrogen, Phosphorus and Potassium.
   B. **FERTILIZER ANALYSIS** is the percentage of N, P & K by weight, always listed in this order.
      examples: 100 lb. bag of 12-6-18 = 12lb(N) 6lb(P) 18lb(K)
      50 lb. bag of 12-6-18 = 6lb(N) 3lb(P) 9lb(K)
   C. **LOW ANALYSIS FERTILIZER** is below 30% total nutrients.
   D. **HIGH ANALYSIS FERTILIZER** is 30% and above in total nutrients.

2. Five Methods Of Fertilizer Application:
   A. **BROADCASTING** is applying a thin layer of fertilizer on the entire soil surface then working into the top layer with a plow or hand tools before planting.
   B. **TOP DRESSING** is applying fertilizer on the soil surface right where plants will be grown.
   C. **SIDE DRESSING** is applying fertilizer at the base of growing plants
   D. **BANDING** is applying fertilizer between the rows of plants, before or after planting.
   E. **FOLIAR FEEDING** is spraying a liquid fertilizer on plant leaves.

3. **Use of Fertilizers**

Five types of important information for use of fertilizers are: PURPOSE (use by plants), EFFECTS (results from too little or too much), DEFICIENCY SYMPTOMS, METHOD OF APPLICATION, and SOURCES.

NITROGEN

A. Purposes: i. Produces fast growth of leaves and soft stems.

ii. Part of every chlorophyll molecule, enzymes and proteins. B. Effects: Too much can focus plant growth on soft tissues instead of:

i. Fibrous tissue, resulting in plants which are easily blown over by wind (ex. bananas and corn).

ii. Flowers & fruits, resulting in harvests that are small or lower quality.

C. Deficiency Symptoms:

i. New leaves are small and very light green color

ii. Old leaves turn yellow and drop off.

D. Application: Easily leached from the soil, best to apply in small amounts at specific times. Leaf crops respond well to foliar feeding

E. Sources: Chemical fertilizers, Animal Manure, Green Manure, Compost.

GREEN MANURE is a term for a legume crop that is grown and then cultivated into the soil to add nitrogen.

PHOSPHORUS

A. Purpose: i. Important in the development of flowers and fruit.

ii. Important in early growth of seedlings.

B. Effects: Lack of P in soils may:

i. Greatly reduce yields of legume crops.

ii. Cause citrus to develop coarse skin, poor shape and sour juice.

C. Deficiency Symptoms: Purple color of leaves, stems and branches.

D. Application: Leaching is not a problem, P moves very little after placement. So, application is best close to roots of the plant and is sometimes placed in bands below seeds or transplanted seedlings.

E. Sources: Chemical fertilizers, Phosphate rock, animal bones, bird and bat droppings.

POTASSIUM

A. Purpose: i. Important in the formation of sugars and starches.

ii. Important in development of storage roots.

iii. Required for opening of stomates.

B. Effects: i. Some plants and fruits are naturally high in K and therefore need large amounts. (Ex. Bananas)

ii. Deficient soils grow plants that do not have strong root systems and are easily blown down.

C. Deficiency Symptoms: i. Older leaves are spotted and curled, sometimes look "burned" around the edges.

ii. Corn plant have yellow streaks in the leaves

D. Application: Not easily leached, except for wood ashes.

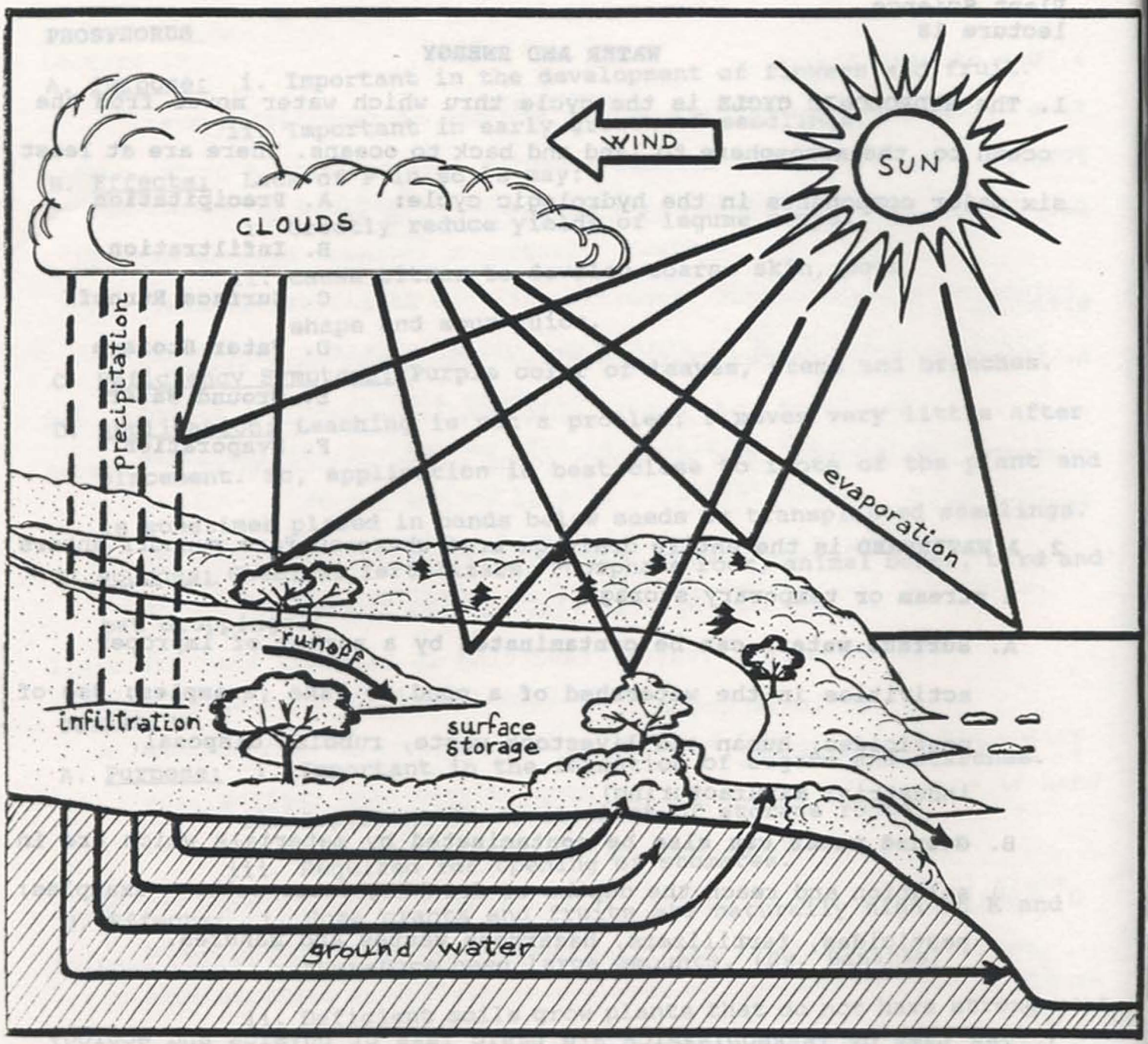
E. Sources: Chemical fertilizer, Compost, Wood ashes.

WATER AND ENERGY

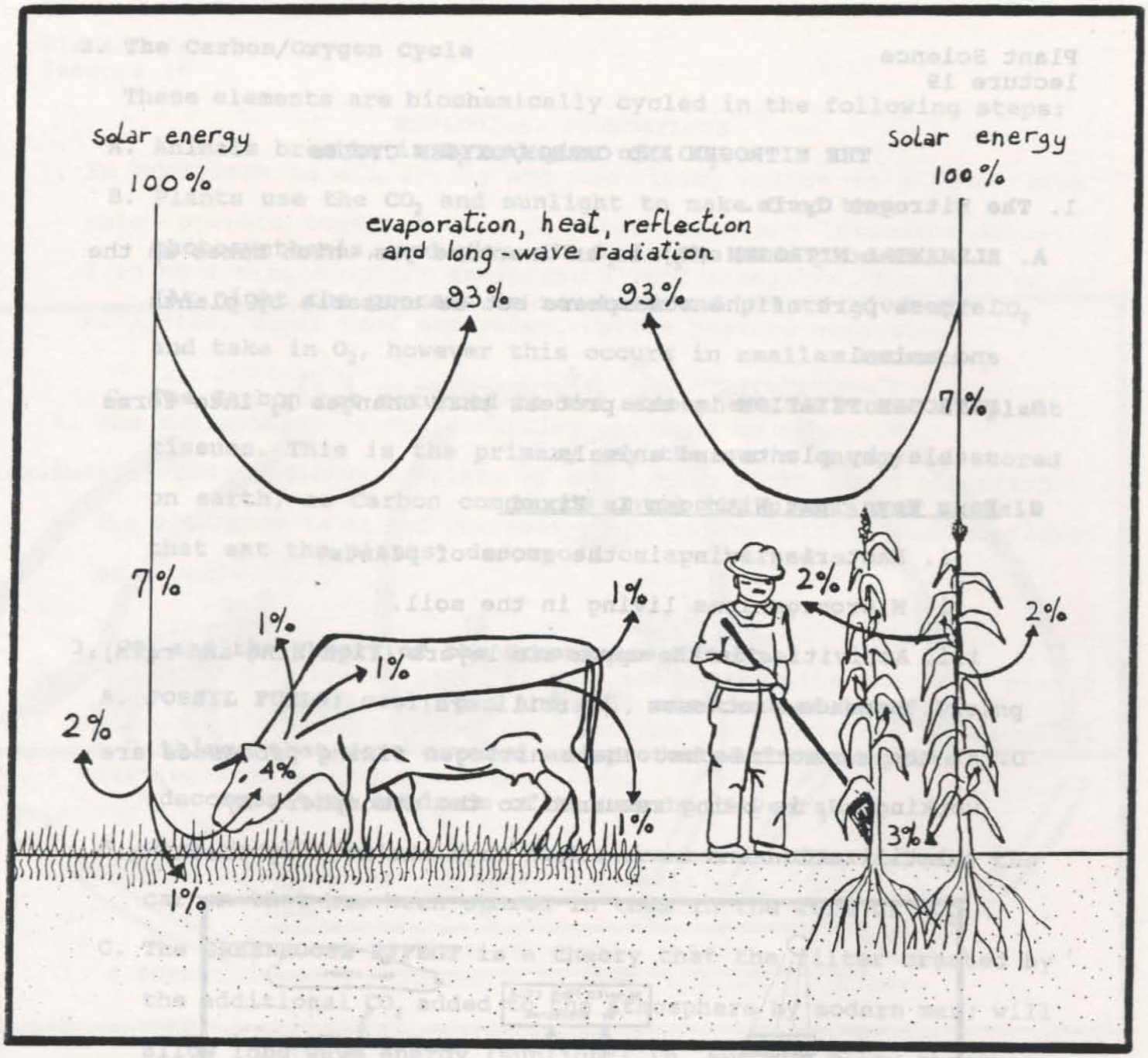
1. The **HYDROLOGIC CYCLE** is the cycle thru which water moves from the ocean to the atmosphere to land and back to oceans. There are at least six major components in the hydrologic cycle:
   - A. **Precipitation**
   - B. **Infiltration**
   - C. **Surface Runnoff**
   - D. **Water Storage**
   - E. **Ground Water**
   - F. **Evaporation**

2. A **WATERSHED** is the entire drainage area where surface runnoff enters a stream or temporary storage.
   - A. **Surface waters can be contaminated** by a number of improper activities in the watershed of a pond or lake (examples; Use of pesticides, human and livestock waste, rubbish disposal, industrial manufacturing)
   - B. **Ground water can also be contaminated** by materials which are in solution and reach the depths of drinking water wells - examples; pesticides, fertilizers, hazardous wastes and manures.

3. **THE LAWS OF THERMODYNAMICS** are basic laws of physics and ecology which explain how energy is cycled throughout the universe.
   - A. The **1st Law of Thermodynamics** is that energy cannot be created or destroyed (however it readily changes form).
   - B. The **2nd Law of Thermodynamics** is that each change of form results in a degradation of energy from a concentrated to dispersed state.



THE HYDROLOGIC CYCLE



LAWS OF THERMODYNAMICS

THE NITROGEN AND CARBON/OXYGEN CYCLES

1. The Nitrogen Cycle.

A. **ELEMENTAL NITROGEN (N_2)** is an inactive gas which makes up the largest part of the atmosphere but is unusable by plants and animals.

B. **NITROGEN FIXATION** is the process that changes N_2 into forms usable by plants and animals.

C. **Four Ways That Nitrogen Is Fixed**

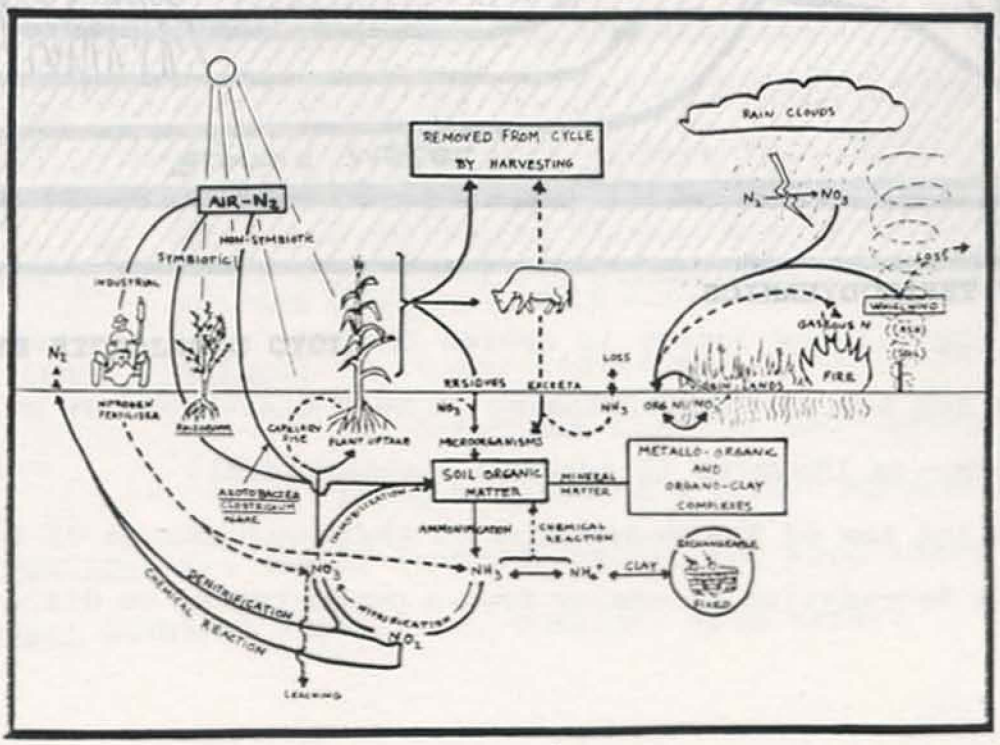
i. Bacteria living in the roots of plants.

ii. Microorganisms living in the soil.

iii. Activities in the upper air layers (lightning and rain).

iv. Manmade processes (fertilizers)

D. At the same time that these nitrogen fixing processes are working, N_2 is being returned to the atmosphere by volatilization and moving down thru the soil by leaching.



2. **The Carbon/Oxygen Cycle**

These elements are biochemically cycled in the following steps:

A. Animals breathe in O_2 and give off CO_2.

B. Plants use the CO_2 and sunlight to make food thru photosynthesis, and give off O_2 in the same process. (At night the process is reversed and plants give off CO_2 and take in O_2, however this occurs in smaller amounts.)

C. The Carbon not returned to the atmosphere is stored in plant tissues. This is the primary way the sun's energy is stored on earth, as Carbon compounds until the plants,and animals that eat the plants) decompose or are burned.

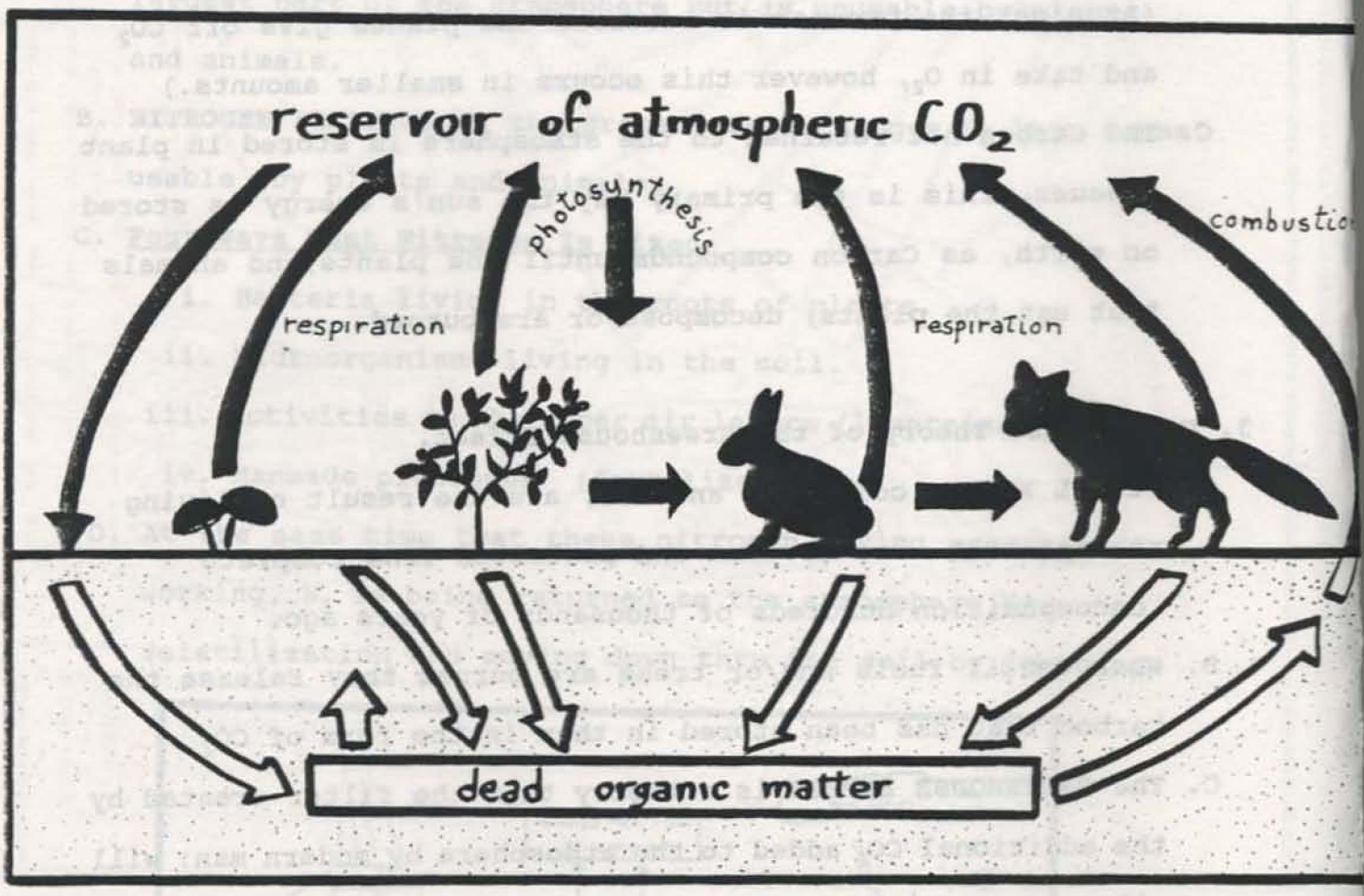
3. **CO_2 and the Theory of the Greenhouse Effect.**

A. **FOSSIL FUELS**; coal, gas and oil, are the result of living things that were covered and protected from complete decomposition hundreds of thousands of years ago.

B. When fossil fuels and/or trees are burned they release the carbon that has been stored in them in the form of CO_2.

C. The **GREENHOUSE EFFECT** is a theory that the filter created by the additional CO_2 added to the atmosphere by modern man; will allow long wave energy (sunlight) in, but not allow shortwave energy (heat) to escape.

D. The predicted results of the greenhouse effect are that; by the year 2050 an increase in the world's temperature by 3.4 degrees worldwide and 3.8 degrees at the poles. It will only require an increase of 3.6 degrees to completely melt the polar icecaps. (These temperatures are in Celcius).



THE CARBON and OXYGEN CYCLE

ECOLOGICAL FOUNDATIONS

1. An **ECOSYSTEM** is all living and non-living things in a given area which operate together through interaction and interdependence, forming a single unit. Examples: a pond ecosystem, tropical forest ecosystem, coral reef ecosystem, cattle pasture ecosystem.

   A. The **ENVIRONMENT** is the nonliving parts of an ecosystem.

   B. A **BIOTIC COMMUNITY** consists of the living parts of an ecosystem.

   C. The **BIOSPHERE** is all of the ecosystems of the Earth's surface viewed as a whole.

2. A **FOOD CHAIN** is the transfer of food energy from the source in plants (producers) through a series of organisms (consumers and decomposers) with repeated eating and being eaten.

EXAMPLE: **Floating plant** → **Prawn (ulavai)** → **Small fish** → **Large fish** → **Man**

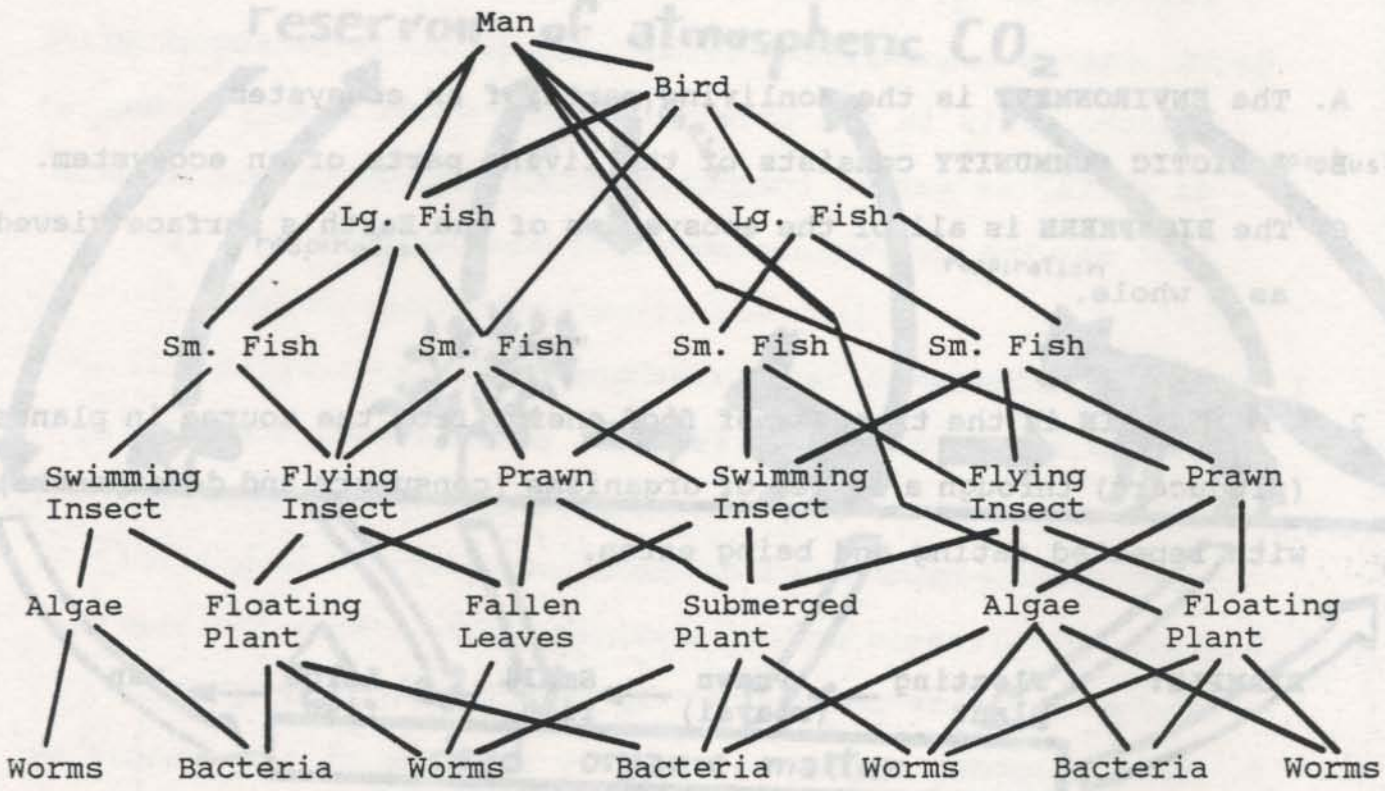
   A. A **PREDATOR** is an organism which eats another organism

   B. A **PREY** is an organism which is eaten

The predator/prey relationship can be viewed from different points, meaning that in the food chain example above; the small fish are predators of the prawn and the prey of larger fish all at the same time.

3. A FOOD WEB is the interconnection of many food chains in a biotic community.

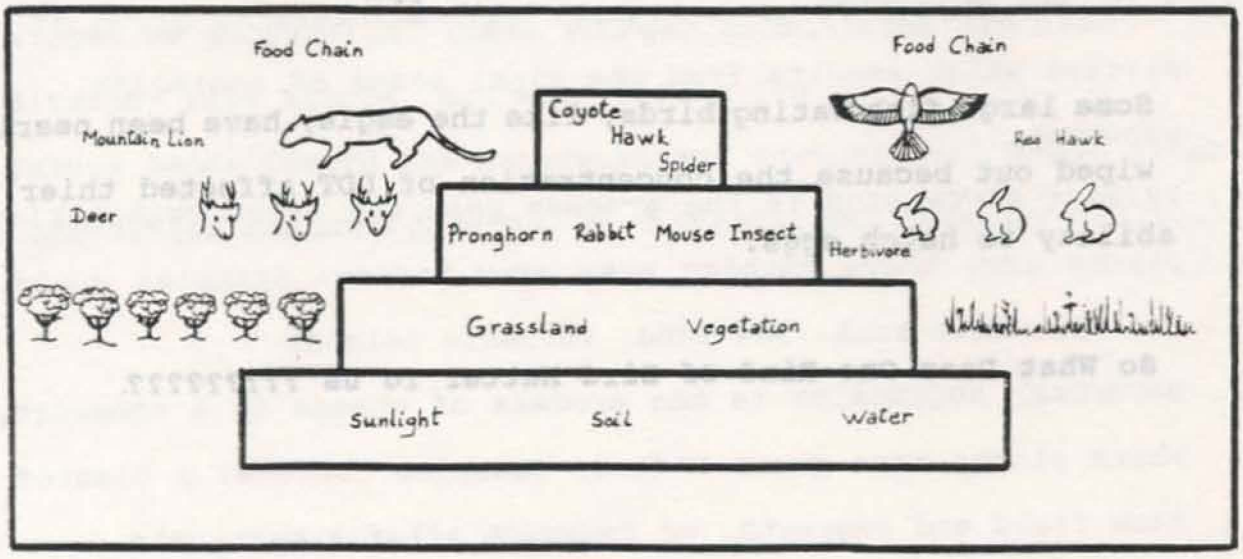
EXAMPLE: FOOD WEB OF A POND ECOSYSTEM



ECOLOGICAL FOUNDATIONS (Continued)

1. A **TROPHIC LEVEL** is the level at which food energy is transferred from one organism to another.
   A. **PRODUCER ORGANISMS** are green plants that use sunlight to make food.
   B. **1st LEVEL CONSUMERS** are herbivores, which means they only eat eat green plants for food.
   C. **2nd LEVEL CONSUMERS** are carnivores, (meat eaters) that eat herbivores for food.
   D. **3rd LEVEL CONSUMERS** are carnivores that eat the 2nd level.
   E. **DECOMPOSERS** are bacteria, mold, & fungi that breakdown dead material for reuse by plants.

2. **A BIOTIC PYRAMID** is a diagram of a community which shows the trophic levels that exist there, usually measured in live weight rather than the number of organisms.



3. **Two Rules of Biotic Pyramids:**

A. 2nd Law of Thermodynamics - energy is lost as we move up the food chain/biotic pyramid by an average of about 10% per trophic level.

Example: It is much more energy efficient to eat grain vegetables (plants) than it is to feed these to animals and eat the animal later.

B. **BIOMAGNIFICATION** is the concentration of specific materials becomes stronger as we move up the food chain/biotic pyramid.

Example: DDT is a pesticide which used to be sprayed to control mosquitoes, it is now found in most organisms on earth, including mother's milk.

DDT Measured in Parts Per Million (ppm)

Water	= 0.00005 ppm
Floating plants	= 0.04 ppm
Small fish	= 0.94 ppm
Large fish	= 1.33 ppm
Eagle	= 22.8 ppm

Some large fish eating birds, like the eagle, have been nearly wiped out because the concentration of DDT affected thier ability to hatch eggs.

So What Does One Kind Of Bird Matter To Us ?????????

4. The Effects Of Removing Or Adding To A Food Web

A. If predators are removed the numbers of their prey will increase and become a problem for all other members of the food web.

Example: The coral reef ecosystem. The Conch is a predator of the Crown Of Thorns. When the Conch is removed (often for sale) the number of Crown Of Thorns, increases rapidly. The Crown Of Thorns is a predator of coral and can wipeout the entire producer level (food) for all other reef creatures.

B. If an organism is added to a food web that does not contain its predators, the new organism will increase and become a problem to the food web.

Examples: The toads and African snails in American Samoa. The bird eating snakes in Guam. Weeds that have no insects or disease for control.

ECOLOGICAL FOUNDATIONS (continued)

1. Diversity And Stability In An Ecosystem

A. **DIVERSITY** means having a large number of different organisms and trophic levels in a biotic community.

B. **ECOLOGICAL STABILITY** is the ability to handle changes in the physical environment (temperature, light, moisture) or resist damages from influx of disease or insects without major damage to the community structure.

2. How Does A Community Become Diverse?

When ecosystems are left alone the rules of thermodynamics, nutrient cycling, and ecology cause the ecosystem to develop and mature in an orderly way:

A. **ECOLOGICAL SUCCESSION** is a term to describe the changes over time in the structure and function of an ecosystem leading up to a climax biotic community.

B. A **CLIMAX COMMUNITY** is a stable, self-maintaining group of species which results from the final stage of ecological succession.

C. **PRIMARY SUCCESSION** is the process when the first communities plants grow where nothing ever grew before. Examples would include; Bare rock, New sand, Volcanic islands

D. **SECONDARY SUCCESSION** is the process of change in a community where plants have grown before. Examples include; a cleared farm field and regrowth, or regrowth after a hurricane.

3. **Rules Of Ecological Succession**

A. It is an orderly process of community development that involves changes in the type and number of species.

B. It results from changes in the environment by the community, although the environment also limits what community can exist there.

C. It ends in a steady state ecosystem which has the greatest biomass, diversity and stability possible within the given environment.

4. **Factors Affecting Succession Can Be Natural or Man Made**

A. Natural Factors Include:

Soil, Climate, Plants, Animals, Fire, and Hurricanes.

B. Man Made Factors Include;

Removal (clearing for plantations forestry, pastures & homes), Introduction (livestock, pests, diseases, foreign plants/weeds), and Pollution (fertilizers, pesticides, industrial wastes).

C. Agriculture, Forestry and Livestock production favor the early stages of succession. These younger communities are less diverse, less stable, but more productive.

D. Nature tends toward the mature climax communities. These older communities are more diverse, more stable, but less productive.

CLOSING THOUGHTS

The planet Earth, our home, is four and a half billion years old. If we imagine all these years squeezed into the six days of creation, it gives us a sense of our place in this world.

"The Earth would be created on midnight of Monday. Life first appears on Tuesday at 12 noon. Life continues to develop until enough chlorophyll has been at work (tying up Carbon) to begin forming fossil fuels on Saturday morning. At four in the afternoon on Saturday, the dinosaurs and great reptiles arrive; and by nine in the evening they are finished.

Four minutes before midnight on this sixth day; something like us, although not really us, begins to appear. One and one half seconds before midnight we invent agriculture. In the next half second we are so successful that the forests surrounding the Mediterranean Ocean have disappeared, and with it the civilization of ancient Sumeria. As these die, a pine tree begins to grow in California and it is still alive today. One third of a second before midnight, Buddha is born, and in the next third of a second Jesus Christ. A fortieth of a second before midnight marks the beginning of the Industrial Revolution, and in another fortieth we discover oil.

At one hundredth of a second before midnight, your parents may have been born. In their lifetime the population of the Earth has increased three times. The use of available resources has increased four times. Between then and now we have used up more resources than all past history in total. Now it is midnight, and many people think that these developments can continue at their present rate."

What do you think ??

(Adopted from comments by David Brower, founder of the Sierra Club and Friends of the Earth.)